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SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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TO IMPROVE MEASUREMENT TECHNIQUES IN AGRICULTURE

M. A. Aver'yanov

In order to solve the problems put before our nation by the Communist Party and the Soviet Government concerning a vigorous, new upsurge in agriculture, a steeper rise in agricultural output, higher productivity of labor, and lower costs of agricultural production, it is necessary, among other things, to ameliorate considerably the application of measurements and controls and to improve the utilization, maintenance, and repair of measuring devices. These demands gain in importance especially in view of the vital problems to be discussed at the December Plenum of the Central Committee of the Communist Party.

If the latest scientific techniques are to be used in agricultural production, accurate measurements must be applied in sectors where almost none had been applied before.

Further developments in agriculture through better crops, higher productivity, and growth of mechanization and automation will also call for special indispensable measuring techniques capable of improving the productivity of labor. It has now become urgent to set up planning offices and tool-producing shops in order to satisfy the needs of agricultural production.

It is necessary to organize the manufacture and mass production of tools and devices based on the latest scientific and technical achievements, permitting long-range measurements, and automation of labor-consuming farm work, including animal husbandry. There is a need for apparatus which would mechanize the delivery and receiving of agricultural products and guarantee the objectivity of data in the delivery of agricultural products (for instance, automatic scales).

Together with a widespread introduction into agriculture of tools already manufactured and those to be manufactured, special attention should be paid to the improvement of existing measuring tools, their proper utilization, and maintenance. Much is being done currently toward the accomplishment of the above-mentioned tasks; however, there are still many shortcomings in the existing technique of measurements, as well as in its application. Special attention, for instance, must be paid to the measuring of humidity at delivery, receiving, and storage of grain.

An efficient method of measuring the humidity of grain delivered to grain elevators and granaries should be worked out, since the existing method, based on drying threshed grain in a drying cupboard, is time-consuming, and comparisons made between electrohydrometer data and humidity data obtained through the drying process point to relatively important differences.

The method for determining both the quantity of milk and its fat content is defective. There is a shortage of essential machinery in dairy farms and the maintenance of existing tools is not organized.

It is very important that petroleum products belonging to RTS, state, and collective farms should be properly accounted for, since this is affecting a number of economic indicators and is connected with the wages of tractor and truck drivers. In many places, the only control is done by way of bookkeeping, and not on the basis of a well-functioning system of measurements, thus failing to stimulate interest in economy in the use of these valuable products.

The checking of farm-machinery fueling and the stock-taking of remaining fuel contents in the tanks is done either without control, or in a haphazard, primitive way.

Many fuel depots belonging to collective and state farms and RTS have fuel tanks constructed without foundations and without proper grading,and many fuel tanks are not equipped with fuel meters. Makeshift measures instead of proper ones are used for fuel distribution in depots and under field conditions. Fueling is done with insufficiently mechanized measuring gauges. The automatic gauge for measuring fuel inputs, designed under the auspices of the Ministry of Agriculture of the RSFSR, is not applied widely enough. Depots are not equipped with densimeters to measure the density of petroleum products, which results in the widespread use of approximate rather than accurate density data.

An inspection conducted by local organs of the Committee for Standardization in the first half of 1959 showed that apparatus,and especially scales,have been set up improperly and were exposed to weather conditions. In a number of RTS, state, and collective farms no responsibility has been assigned for the safeguarding of measuring techniques and no personnel has been assigned to oversee the proper utilization of machinery. A number of state control laboratories on measuring techniques are not distributing information regarding the utilization of measures and tools, or their maintenance. The fact that measuring tools and other measuring devices are in poor shape is responsible for the low quality of farm machinery maintenance, as well as for its short-lived performance. Thus, a number of RTS in the Moldavian SSR are insufficiently equipped with measuring tools necessary for the repair of farm machinery. Owing to the lack of tools, the usefulness of machine parts under repair cannot be determined accurately. Their fitness is often determined by eye, according to their appearance.

It is also necessary to overcome the substantial organizational shortcomings which hinder the repair of measuring devices. For example, in certain areas of the Leningrad district, repair jobs are limited to certain tools only, so that other tools have to be sent in many cases to the workshops in Leningrad.

In order to improve the condition of the measuring technique in agriculture, it is necessary to move the repair stations closer to RTS, collective, and state farms, to set up repair shops in the larger RTS,and equip mobile workshops able to repair measuring devices on the spot, as has been done in a number of republics, regions, and districts.

The Ministry of Agriculture of the Kirghiz SSR has organized mobile electro-laboratories at the "Sel'élektro" station. Repair and checking points for linear and angular measuring devices have also been organized.

In many districts of the Ukrainian SSR, GAZ-51 motor cars have been equipped to serve as mobile repair shops by weight-repair stations, district weight-repair shops, and district offices of "Zagotzerno" and "Sel'élektro."

In the districts of Zaporozh'e and Odessa, the District Executive Committees have arranged for a sufficient number of trucks to be made available by motor pools to repair stations, so that measuring instruments and tools could be repaired directly at collective and state farms.

The Chernigov District Executive Committee has decided to organize tool-repair shops in five RTS and mobile laboratories at the "Sel'élektro" station for the maintenance of electrical equipment on the spot.

State control laboratories for measuring techniques should participate actively in this work. If the standard of measuring equipment is to match the level of our highly mechanized socialist agriculture and to stimulate its further growth, laboratories for agricultural measurements should be properly equipped and staffed, just as those working for industry.

It is the duty of measuring technique personnel to use their experience, knowledge, and know-how to improve both the existing conditions and the utilization of measurements in agriculture.

NEW RULES FOR STATE TESTING OF MEASURES AND MEASURING INSTRUMENTS

L. M. Zaks, N. M. Karlin, and N. I. Tyurin

The Committee of Measures and Measuring Instruments attached to the USSR Council of Ministers has prepared rule 2-59 for state testing of measures and measuring instruments, both new ones and those manufactured by our industry. These rules have been worked out to replace rule 2-56 and will be introduced on April 1, 1960.

The new rules have been compiled to accord with the tasks set by the 21st Congress of the CPSU and the June Plenum of the CPSU Central Committee and aim at accelerating technical progress and a speedy introduction of new techniques.

The main task of the state testing of measuring instruments is the raising of their performance up to the requirements of our national economy and the latest standards of our own and foreign technology.

These tests have acquired a particular importance in connection with the growing role played by metrology in production automation and the development of scientific research.

Basic propositions. The most important characteristics of the new rules for state testing of measures and measuring instruments are:

1. Concentration of attention on testing experimental models of measures and instruments intended for mass production. Thus, state tests will form an organic part of the general development of experimental models of measuring instruments and their transfer to mass production.

State testing at this stage of production is of great practical importance. It safeguards industry from unproductive expenditure of money and time on organizing mass-production equipment. Thus, the introduction of the latest instruments into industry is speeded up and the overlapping of various tests, which used to occur in the past, is eliminated (customer's inspection, various commissions, state tests.)

2. In order to ensure a most thorough and all-embracing testing of experimental models, a much wider participation of interested organizations is provided. This step will enhance testing facilities both with respect to the availability of qualified personnel, and special testing equipment which belongs to different organizations. In addition, to the Committee's Institutes, this testing can be entrusted to other organizations (industrial institutes, etc.). For the testing of complex and especially important instruments, interdepartmental commissions either appointed by the Committee or by the corresponding departments in agreement with the Committee can be set up.

The new rules provide for a compulsory meeting of the interested organizations' representatives for a discussion of the test results. The experience gained by the Committee's All-Union Scientific Research Institute, which has regularly called such meetings for the last two years, confirms the expediency of this measure. The Committee of Standards, Measures, and Measuring Instruments organizes the testing of instruments through its Institutes. The test programs should in all cases be approved by the directors of the Committee's Institutes.

3. In order to encourage a constant improvement in the measuring instruments produced by our industry it is laid down that:

a) the Committee provide permits for mass production of instruments for a limited period only (5 years), and in renewing the permit check that the instruments' performance is up to the latest standards of measurement technology and the requirements of our national economy;

b) in routine testing carried out by the Committee's agencies constant attention be paid to the improvement of the measuring instruments produced by our industry.

Testing of experimental models. The rules provide that models intended for mass production must be submitted for state testing in a completely finished condition according to specifications.

In many instances "raw" designs or models were presented in the past for testing. As the result of this, models had to be returned to the designer several times.

The rules establish a definite list of documents which must be presented together with the experimental model of the instrument. Among these documents special attention should be drawn to the development report or the explanatory note to the technical specification. This document should contain technical and economic justification for the instrument's performance, and include the instrument's schematics and specifications, and relevant calculations and test results, as well as data comparing it with the best models made in the USSR and abroad; an analysis of errors and grounds for the testing methods adopted; a list of the proposed manufacturing plants and consumers; and a tentative mass-production cost of the instrument.

The state testing experience provides, unfortunately, many instances of instruments being developed without due study of the latest achievements in the relevant branches of instrument making.

It is obvious that the development of new measuring instruments should be entrusted to organizations and establishments sufficiently competent in that particular sphere, and all the theoretical problems should be solved in consultation with the appropriate basic organizations.

The stricter test requirements are reflected in the raised standard of reports (or deeds of an interdepartmental commission).

They must contain:

a) the results of the instrument model tests and their analysis;

b) a theoretical evaluation of the instrument and its comparison with the best models of similar instruments, noting the degree to which the latest metrological achievements were utilized;

c) an evaluation of the degree to which the specified and duly approved requirements were met;

d) notes and proposals regarding the models and technical specifications;

e) recommendations regarding the expediency and manner in which the experimental model should be prepared for mass-production or the production of a test batch. At the same time an opinion should be expressed on the possibility of discontinuing production of similar instruments as being obsolete;

f) recommendations on the procedure, the program, and the place for testing instrument models in a test batch or in the first consignment of mass-production;

g) if it is considered necessary to carry out additional field testing, the report should suggest the program and manner of these tests.

The recommendations based on the test results and the decisions of the technical conferences are presented to the Committee by the Committee's Institute which conducted, organized, or took part in the testing.

Considering the compulsory nature and stricter requirements with respect to experimental models, the new rules provide simplifications in the testing of mass-produced instruments. If, for instance, an experimental model which is presented for testing incorporates in its construction and design mass-production requirements, the possibility is provided of granting the manufacturing plant permission to supply these instruments commercially without presenting for testing a mass-produced model.

The new rules empower the Committee to grant permission for the production of test batches not only on the basis of test results, but also before experimental models are submitted for testing. This provision is mainly made for cases when it is required, in the development of instruments which are intended for complicated operational conditions, to check thoroughly the reliability of their operation. After the completion of testing and the appropriate alterations to the design, the experimental models of the instrument must be presented for state testing accompanied by the data describing their operational characteristics.

The rules provide that when an experimental batch of instruments is produced each of them must have a label "experimental" attached to it. This label will indicate to the consumer the necessity of carefully observing the instrument and reporting the observations to the manufacturing plant or the Committee's agencies. This will lead to the accumulation of vast data on the behavior of instruments under varied operational conditions in addition to the information obtained from specially organized field tests.

The procedure for planning state tests of measuring instruments by the Committee on the basis of the information provided by the planning organizations and departments remains the same, and provides for the possibility of altering the testing plan within one year.

Testing of mass-produced instruments. This refers, above all, to the testing of the first consignment of new instruments mass-produced according to an approved experimental model.

These tests can be carried out by a Committee Institute or a State Inspection Laboratory, whichever is the more convenient. The possibility of the participation in these tests of outside specialized organizations is not excluded. The tests are based on the experimental model tests and the resulting recommendations and the draft test plan. The plan can be altered or supplemented in the light of the factors discovered in the preparations for testing.

The same group of tests includes that of the first batch of mass-produced instruments made according to the specifications supplied by another plant which has already obtained the right for the commercial supply of these instruments. These tests are carried out according to the test plan for the first consignment of new mass-produced instruments with any necessary additions.

Test reports on instruments whose mass-production has been undertaken by a plant, including those which were undertaken from data supplied by another plant, are examined by the Committee's Institute which supervised the testing of the instrument's experimental model. Having examined the report, or if necessary discussed it at a technical conference, the Committee's Institute in question presents an appropriate recommendation.

An instrument whose mass-production has been undertaken for the first time is assigned a registration number by the Committee.

It should be noted that after the Committee's order has been issued and before the actual manufacturing permission is granted a final check is made of the plant's capacity for mass-production with respect to its measuring and test equipment. This requirement is based on previous experience, when certain plants produced instruments for a long time without being able to check one of its important parameters.

In the light of the decisions of the June Plenum of the CPSU Central Committee, routine testing of the instrument-making plants' production, in both periodic and surprise inspections, has acquired special significance. These tests were formerly known as control tests and they pursued limited objectives, such as quality control and conformity to the approved sample.

Under the new regulations, the aim of these tests has been expanded and they become, as it were, the continuation of the testing of new instruments which involves the checking in all routine tests of whether the tested instruments are up to the latest standards and requirements of our national economy, since in the interval between the routine tests important changes in the given sphere of metrology may have occurred, for instance, instruments based on a new principle may have appeared and passed their state tests, etc. Data on the operational properties of instruments also acquires great importance in routine testing. This data must be collected both by the establishments and the Committee agencies.

As a rule, the tests at the plants are carried out by the Committee agencies in conjunction with representatives of the interested establishments, especially those which use the instruments. Models for such tests are taken from stock in required quantities.

If manufacturing defects are found in these tests, such as deterioration of quality as compared with the approved model, etc., the head of the local agency of the Committee requests the plant to eliminate the defects and checks that it is done. If these instructions are not fulfilled, the Committee takes appropriate measures, even forbidding, if necessary, the production of these instruments.

If the necessity of improving the design of an instrument or changing over to the production of new instruments is established, the head of the Committee's agency requests the plant to take, in a given time, the required steps. The Committee and the Department in charge of the plant are informed of the requests put to the plant.

In conclusion, the rules stress the obligation of the directors of Institutes, representatives of the Committee attached to the All-Union Council of Ministers, and Chiefs of the State Inspection

Laboratories of Measuring Equipment not to permit the commercial mass production of instruments which have not been approved by the Committee or passed for commercial production as shown on the list attached to the new rules.

A METHOD OF DETERMINING VARIANCE IN THE PRESENCE OF A LINEAR SYSTEMATIC ERROR

A. Yu. Gidel'

The term "variance" is defined in metrology as the variation in measuring instrument readings with constant external conditions. The variance is equal to the maximum difference between repeated readings of an instrument. However, measurements are often made with variable external conditions, for instance with varying temperature, or under the effect of elastic strain, when readings rise or fall progressively even in the absence of a variance.

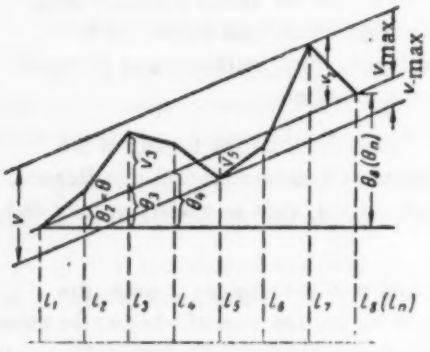


Fig. 1. $l_1, l_2, l_3, \ldots, l_n$ are readings taken at equal time intervals; $\Theta_2, \Theta_3, \ldots, \Theta_n$ are values of the systematic progressive error for individual readings; Θ is the constant systematic progressive error increment; $\underline{n}$ is the number of readings; $v_1, v_2, v_3, \ldots, v_n$ are the differences between the actual readings and the theoretical values of measurements with a systematic progressive error, but without a variance; $v_{+\max}$ is the largest positive value of v_i; $v_{-\max}$ is the largest negative value of v_i; and $\underline{v}$ is the variance of a series of measurements.

The definition of the term "variance" accepted in metrology is obviously unsuitable for such measurements, since in defining "variance" in a series of measurements as the difference between the largest and smallest reading, we shall obtain results which will depend on the number of readings taken for the calculation of the variance. With each succeeding reading the variance will either rise or fall and its determination in the normal sense of the word becomes impossible, since we are dealing here with a variable which is a function of the number of readings or the duration of measurement. Examples of such series are given in Tables 1 and 2. Here the difference between the maximum and minimum instrument readings corrected for the systematic error should be taken as the variance.

For determining the variance in the presence of a linear systematic error (proportional to time) we have developed a method whose essence is outlined below.

Let us assume that in repeated measurements of a variable a series of readings has been obtained whose values increase proportionately to time (Fig. 1).

For the solution of this problem, let us assume that $v_1 = 0$; $v_n = 0$, which is always possible in practice.

From Fig. 1, we obtain:

$$l_2 = l_1 + \Theta_2 + v_2 = l_1 + \Theta + v_2;$$
$$l_3 = l_1 + \Theta_3 + v_3 = l_1 + 2\Theta + v_3;$$
$$\ldots\ldots\ldots\ldots\ldots\ldots$$
$$l_k = l_1 + \Theta_k + v_k = l_1 + (k-1)\,\Theta + v_k;$$
$$\ldots\ldots\ldots\ldots\ldots\ldots$$
$$l_n = l_1 + \Theta_n = l_1 + (n-1)\,\Theta.$$

Whence:

$$\theta = \frac{l_n - l_1}{n-1}. \qquad (1)$$

Let us determine the value of v_i:

$$v_1 = 0;$$
$$v_2 = l_2 - l_1 - \theta;$$
$$v_3 = l_3 - l_1 - 2\theta;$$
$$\cdots\cdots\cdots$$
$$v_k = l_k - l_1 - (k-1)\theta;$$
$$\cdots\cdots\cdots$$
$$v_n = 0.$$

Having thus obtained a series of deviations $v_1, v_2, v_3, \ldots, v_n$, we find among them $v_{+\max}$ and $v_{-\max}$, the sum of whose absolute values is the variance of the series of measurements:

$$v = |v_{+\max}| - |v_{-\max}|. \qquad (2)$$

TABLE 1

Readings l_i	$l_{\theta i} = l_1 + (i-1)$	Differences $v_i = l_i - l_{\theta i}$
12.10	12.10	0
11.90	11.87	+0.03
11.55	11.64	−0.09
11.10	11.41	−0.31
10.85	11.18	−0.33
10.70	10.95	−0.25
10.40	10.72	−0.32
10.30	10.49	−0.19
10.30	10.26	+0.04
10.25	10.03	+0.22
9.65	9.80	−0.15
9.45	9.57	−0.12
9.20	9.34	−0.14
8.90	9.11	−0.21
8.90	8.88	+0.02

Let us illustrate by an example the application of this method. In determining the variance of a thickness gauge a certain thickness was measured 15 times (Table 1; the values are given in the instrument scale graduations).

The constant variation of the values of l_i points to the presence of a systematic progressive error, which is apparently connected with the elastic strain in the instrument components; the temperature variations of the instrument during measurements did not exceed 0.02° C and could not have caused any temperature error. It is known that the elastic strain follows a linear law; it will be shown below that the series of measurements given in Table 1 is also linear.

The constant systematic error increment θ, which would have been apparent in the readings in the absence of a variance is determined from (1)

$$\theta = \frac{l_n - l_1}{n-1} = \frac{8.90 - 12.10}{14} = -0.229 \simeq -0.23 \text{ divisions.}$$

Values $l_{\theta i}$ obtained by consecutive variation of the first reading (l_1) by $(i-1)\theta$ represent the theoretical values of measurements, which would have been obtained in the absence of a variance and a linear variation of readings, for instance, due to elastic strain.

Individual differences (v_i) of the values of l_i and $l_{\theta i}$ represent the deviations of actual readings from their theoretical values. The variance (v) of the instrument is determined from (2) and is equal to the sum of the absolute values of the largest positive (+ 0.22) and the largest negative (− 0.33) deviations:

$$v = 0.22 + 0.33 = 0.55 \text{ scale divisions.}$$

By means of a table of v_i differences, it is possible to check whether it is correct to assume that the systematic error is linear. In fact, the largest deviation is equal to 0.33 of a division, which amounts only to

3% of the corresponding value of the reading l, and this value includes, in addition to the deviation from the linear law, also the deviation due to the variance.

TABLE 2

Reading l_i	$l_{\Theta i}=l_1+(i-1)\bullet$		Difference $v_i=l_i-l_{\Theta i}$
	calculated	round figures	
13.30	13.300	13.30	0
13.00	13.293	13.29	−0.29
13.10	13.286	13.29	−0.19
12.90	13.279	13.28	−0.38
13.30	13.272	13.27	+0.03
13.10	13.265	13.26	−0.16
12.80	13.258	13.26	−0.46
13.00	13.251	13.25	−0.25
13.00	13.244	13.24	−0.24
13.10	13.237	13.24	−0.14
13.00	13.230	13.23	−0.23
13.00	13.223	13.22	−0.22
13.10	13.116	13.22	−0.12
13.00	13.209	13.21	−0.21
13.20	13.202	13.20	0

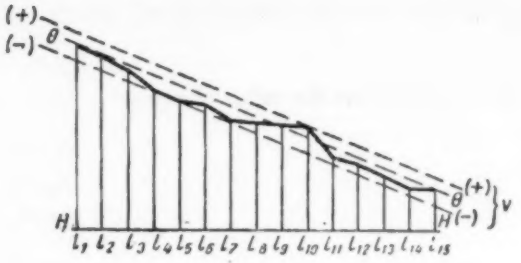


Fig. 2. H——H is the base line from which measurements are taken: $l_1, l_2, l_3, \ldots, l_{15}$ are the values of the actual readings of l_i, drawn to any scale convenient for subsequent measurements; ∧∨∧ is the curve of the actual readings; Θ−−−Θ is the straight line drawn through the points corresponding to the theoretical values of $l_{\Theta i}$ (Table 1); (+)−−−(+) is a straight line parallel to Θ−−−Θ, and passing through the point of the maximum positive deviation (v_{+max}) of the actual readings curve from the straight line Θ−−−Θ; (-)−−−(-) is the straight line parallel to Θ−−−Θ, and passing through the point of maximum negative deviation (v_{-max}) of the actual readings curve from straight line Θ−−−Θ.

The variance can be determined not only by calculation, but also graphically. Let us examine Fig. 2, which reproduces graphically the data of Table 1.

The distance between the straight lines (+)−−−(+) and (-)−−−(-) measured normally to H−−−H is equal to the sum of deviations v_{+max} and v_{-max}, i.e., it represents variance $\underline{v}$ of the instrument.

The determination of the variance in the absence of a systematic progressive error, i.e., under constant external conditions, obviously corresponds to $\Theta = 0$. In order to confirm this reasoning let us calculate the variance of the series of measurements given in Table 2 by the method given above (a) and by the normal method (b).

a) $\Theta = \dfrac{13.20-13.30}{14} = -\dfrac{0.10}{14} \simeq -0.007;$

$v_{+max} = +0.03;$

$v_{-max} = -0.46;$

$v = 0.03 + 0.46 = 0.49;$

b) $v = 13.30 - 12.80 = 0.50.$

It will be seen that the results obtained by the two methods differ by an amount which is negligible in determining the variance. This is another confirmation of the correctness of the above method.

Strictly speaking, the limits method does not provide an absolutely accurate result, since the variation of error Θ is seldom linear and since the direction of the line Θ−−−Θ depends to a certain extent on the value of the last reading, but the figure thus obtained is sufficiently accurate for the determination of variance.

SUMMARY

1. The determination of the variance of a series of measuring instrument readings is possible not only with constant external conditions but also in the presence of a systematic error.

2. The method here developed provides the determination of the variance of instrument readings in the presence of a systematic progressive linear error.

3. The determination of the variance by this method is possible both by calculation and graphically.

4. The definition of the term "variance" adopted in metrology is a particular case of the general variation in which the readings are affected by a systematic error.

LINEAR MEASUREMENTS

STABILITY OF BLOCK GAUGES

A. Z. Polkova

Instability of the material is one of the main causes of lowered accuracy of steel block gauges.

The permissible instability of material for block gauges established by OST 85,000-39 was large, and made it impossible to extend the intervals between periodic tests of block gauges. GOST 9038-59, which replaced OST 85,000-39, considerably raised these requirements; thus the permissible instability for zero grade block gauges was set at 0.5 μ and for the second grade at 1 μ per meter per year, instead of the 1.5 μ for the zero grade and 3 μ for the remaining grades established by OST 85,000-39.

Results obtained at the Sverdlovsk Branch of the All-Union Scientific Research Institute of Metrology in testing the stability of block gauges, and its effect on the accuracy of measurements, confirm the correctness of the tolerances established by the new standard.

TABLE 1

Manufacturing Plant or Firm	Variations in the dimension of 1 m per year, μ	
	maximum	minimum
"Krasnyi Instrumental'shchik"	+ 4.33	− 0.08
"Kalibr"	+ 3.95	− 0.28
Johanson Co.	+ 4.38	+ 0.45
G. Werke	+ 0.47	+ 0.19

The instability of block gauges was determined by means of observing the variations in the size of individual gauges due to natural ageing (Table 1) and by examining the statistical material in checking block gauges of the first and second grade.

Table 1 includes only gauges whose sizes were checked by the absolute interference method of measurement. The data of Table 1 show that among the gauges now being used there are some whose material has an instability which exceeds not only the new, but also the old tolerances set by OST 85,000-39. Gauges of the firm G. Werke were found to be highly stable. Among these gauges not a single one exceeded the instability of 0.5 μ (per 1 m per year).

In order to determine the effect of the gauge instability on the measurements of their length, we examined the statistical material accumulated during 6 years of measurements made with a first grade set (of the G. Werke) and plotted curves of the random error distribution.

An analysis of the curves with empirical (for 846 measurements) and theoretical distributions showed that the distribution of random errors follows the normal distribution law.

The limiting errors of measurement for the duration of the certificates of 1, 2, and 5 years were determined, at first excluding the instability of gauges between the checking times and then including the instability of gauges taken as a random error of measurement.

The errors of measurement obtained in the first instance are the same for all durations of the certificates and gauges of the same nominal dimensions and are within the limits set for the first grade. For gauges exceeding 50 mm in length a considerable increase in the limiting error was observed with an increasing length of the gauge.

The values of the limiting errors obtained in the second instance were within the first grade tolerances only for certificates of 1 and 2 years' duration. The errors calculated for certificates exceeding 2 years' duration are greater than the specified tolerances.

It should be noted that the gauges included in this set (10 to 100 mm in length) changed their dimension within the limits of 0.5 μ per 1 m per year.

Thus, if precision block gauges are made with material which conforms to the instability tolerances of the new standard, the interval between the checking periods of these gauges can be increased to 2 years. This measure would save a lot of time spent in checking first and second grade gauges.

In order to raise the stability of the end measures made by our industry, it is necessary to work out the optimum stabilizing conditions for the material used and apply speedier methods of checking the stability of gauges during their manufacture.

The problem of stabilizing the material used in the production of modern block gauges is receiving considerable attention.

For steels with a low alloy content, stabilization is considered to be completed when a 100% martensite structure is obtained. Such steels (for instance, those with a content of 1.45% Cr, 0.35% Mn, and 1% C) are stabilized by repeated alternate heating and cooling; the gauges are cooled at -75 to $-85°$ C for 6-8 hours (depending on the length of the gauge) and then allowed to heat up to room temperature, next they are annealed at a temperature of 110° C for 3 hours in a gas oven in order to release internal tensions. Full stabilization is attained after 8-10 such cycles of cooling and annealing [1].

For certain steels (for instance 0.90% C, 1.70% Mn, and 0.25% Si) stabilization consists in heating at 200-210° C for 18 hours [2].

Foreign specifications for block gauges (Britain, Germany) do not include tolerances for the instability of materials due to natural ageing, since the stability of materials is checked during the manufacture of block gauges by means of speedy methods.

It is known from published data that in the production of block gauges abroad certain speedy methods of checking stability are used.

TABLE 2

Nominal dimension, mm	Manufacturing Plant or Firm	Change in the dimension after boiling in the solution (in 100 mm), μ	Change in the dimension due to natural ageing in 1 m per year, μ
100	"Kalibr"	+ 0.49	+ 3.95
100	G. Werke Co.	− 0.24	+ 0.36
100	Johanson Co.	+ 0.18	0
50	Matrix Co.	− 3.78	− 3.7

One of the methods consists in heating the gauges in a boiling 0.5-1% solution of potassium bichromate in water. The gauges are considered to be stable if after 24 hours of heating the change in their size does not exceed 2 μ inches per inch of length (or 0.2 μ per 100 mm of length). Several gauges were tested for comparison purposes by this method (Table 2).

These tests show that the block gauges whose dimensions change least in natural ageing received the smallest change in heating. Gauges whose stability was within the limit of 0.5 μ changed their dimension in

heating approximately within the specified amount (± 0.2 μ per 100 mm). There are reasons to believe that the tolerance specified for this method of measuring provides a high stability of gauges with time.

At present a number of methods are used for stability testing of gauges by means of determining the amount of residual austenite. The x-ray diffraction method provides an evaluation of the amount of austenite in steel with an accuracy of some 0.5% [2].

An electronic method provides by measuring permittivity an evaluation of the difference in the content of austenite and annealed martensite in a given sample as compared with reference samples which have a known percentage of austenite [2].

SUMMARY

1. The tolerances for the instability of material established by OST 85,000-39 for block gauges were too wide and made it impossible to extend the time interval between the periodic tests of first and second grade gauges and also prevented the improvement of the precision of block gauges.

Moreover, among the gauges in use there is a considerable percentage with a material instability which exceeds the one set by the standard.

2. The stricter tolerances for material stability of block gauges established by the new standard are rational and help to improve the precision of block gauges and increase the interval between periodic checks.

3. One of the methods of raising the stability of block gauges is the development of optimum methods of stabilization (artificial ageing) for each brand of steel used in the manufacture of block gauges.

4. An indispensable condition for raising the precision of block gauges is the checking of gauges for stability during their manufacture. For this purpose speedy and precise methods of checking stability which would provide a high stability of the gauges in time should be developed.

LITERATURE CITED

[1] R. A. Gierlich, Producing Gauge Blocks to Millionths, Machinery 59, 6 (1953).

[2] Metrology of Gauge Blocks, NBS, Circular 581 (April, 1957).

HYDRAULIC METHOD OF MEASURING LENGTH

V. G. Shtein

Hydraulic instruments for linear measurements should, in principle, be simple in construction and durable, since they have no mechanical transmitting components. Such instruments were proposed by certain foreign authors. This idea, however, was not developed and the suggested designs were not used in practice mainly owing to the difficulty arising from temperature errors whose compensation would have complicated the instruments and deprived them of the advantages listed above.

In order to obtain a stable operation of the instrument it was proposed to make additional scales or chambers, introduce a third mark on the scale, make the scale movable and readjust its zero for temperature variations, introduce compensating stoppers into the chamber, etc.

An analysis and investigation of the effect of all the elements on the nature of the temperature errors showed the possibility of making a hydraulic distance gauge without compensating devices.

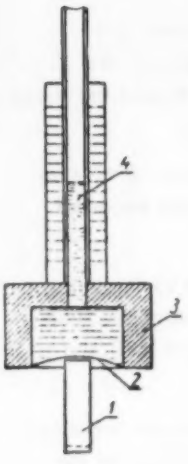


Fig. 1

The practical application of the hydraulic method for measuring lengths consists in the displacement of the measuring tip 1 (Fig. 1) which presses against a diaphragm 2, and forces out liquid (water) from vessel 3 into a glass tube 4 which is calibrated in units of length. There exists a certain relation between the linear displacement of the tip and the displacement of the water level in the tube; having calculated this relation it becomes possible to obtain an instrument of the highest precision.

Assuming that the diaphragm can be represented as a cone with a height equal to the displacement of the measuring tip, this relation can be expressed by the formula

$$\frac{1}{3}\cdot\frac{\pi D^2}{4}H=\frac{\pi d^2}{4}h, \tag{1}$$

whence

$$K=\frac{h}{H}=\frac{1}{3}\left(\frac{D^2}{d^2}\right), \tag{2}$$

where K is the transfer ratio;
D is the internal diameter of the vessel;
d is the internal diameter of the tube;
H is the linear displacement of the tip; and
h is the displacement of the liquid in the tube.

By assuming the value of the scale graduation as 0.001-0.002 or 0.005 mm and taking various transfer ratios, and an internal diameter for the vessel, or a graduation of the scale, it is possible to calculate the remaining basic parameters of the instrument.

Let us now examine the component elements of the temperature error and determine the possibility of eliminating them.

In a general form the increment of the volume ΔV_t and the variation in the height of the meniscus Δh_t for a temperature change of 1° C is represented by the formula

$$\Delta V_t=V_0\alpha\cdot 1^\circ=\Delta h_t\frac{\pi d^2}{4}, \tag{3}$$

$$\Delta h_t=\left(\frac{D^2}{d^2}b+l\right)\alpha\cdot 1^\circ, \tag{4}$$

where D is the internal diameter of the vessel;
d is the internal diameter of the tube;
V_0 is the volume of liquid in the vessel and the tube at 20° C;
b is the height of the vessel;
l is the height of the liquid in the tube; and
α is the bulk temperature coefficient of the liquid.*

Assuming the liquid to be water which has a bulk temperature coefficient of $2\cdot 10^{-4}$, we obtain:

$$\Delta h_t=\frac{D^2}{d^2}b\cdot 2\cdot 10^{-4}\cdot 1^\circ+l\cdot 2\cdot 10^{-4}\cdot 1^\circ. \tag{5}$$

* The bulk temperature coefficient of the metal can be neglected in formula (4) since the bulk temperature coefficient of normal steel is $^1/_7$, and that of tungsten steel $^1/_{20}$, of the bulk temperature coefficient of water.

An examination of the data obtained in (4) and (5) leads to the following conclusions:

a) The temperature error will fall with a decreasing diameter of the vessel and rise with a decreasing diameter of the tube.

The decreasing of the diameter of the vessel with a constant diameter of the tube is prevented by a simultaneous diminution of the scale division h; for instance, for K = 500, D = 100 mm, d = 2.58 mm the graduation is h = 0.5 mm. If for the same conditions, we assume that D = 50 mm, K will equal 125 and the value of the graduation will be h = 0.12 mm, which cannot be achieved in practice.

b) The temperature error falls with a decreasing height of the vessel. Thus, for D = 100 mm, d = 1 mm and b = 10 mm, the error $\Delta h_t = 20$ mm; with the same values of D and d and b = 2 mm, the error becomes $\Delta h_t = 4$ mm.

TABLE 1

Calibration, mm	Height of vessel, mm	Temperature error Δh_t (in μ) for temperature variation of:									
		1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
0.001	1	0.3	0.6	0.9	1.2	1.5	–	–	–	–	–
0.001	2	0.6	1.2	1.8	2.4	3.0	–	–	–	–	–
0.002	1	0.3	0.6	0.9	1.2	1.5	–	–	–	–	–
0.002	2	0.6	1.2	1.8	2.4	3.0	–	–	–	–	–
0.005	1	0.12	0.24	0.36	0.48	0.60	0.72	0.84	0.96	1.08	1.2
0.005	2	0.24	0.48	0.72	0.96	1.20	1.44	1.68	1.92	2.16	2.4

c) The temperature error due to the volume of the liquid in the tube and the size of the graduations is insignificant (approximately 1.5%) and can be neglected.

Thus, in practice, the temperature error can only be reduced by decreasing the height of the vessel to its minimum convenient value of 1 mm.

For D = 100 mm, d = 2 mm and h = 1 or 2 mm the temperature error is shown in Table 1.

The figures given in Table 1 for the temperature error of instruments with various values of graduations and heights of vessels show that the errors due to temperature deviations from normal (20° C) in the room where the hydraulic distance gauge is located do not exceed the tolerances specified for precision distance gauges by OST 20,102 and instruction 133-55 of the Committee of Standards, Measures, and Measuring Instrument, provided:

the temperature deviation from normal in the measuring premises does not exceed ± 8° C for instruments with a graduation value of 0.005 mm and b = 2 mm, and ± 10° C for b = 1 mm;

and for instruments with a graduation value of 0.002 mm and b = 2 mm ± 1° C, and for b = 1 mm ± 3° C.

Thus, hydraulic distance gauges with graduation values of 0.002 mm can be used in measuring laboratories, and those with a value of 0.005 mm in production shops.

Distance gauges with graduation values of 0.001 mm can only be recommended for laboratories which maintain a normal temperature with deviations not exceeding ± 1° C.

There are reasons to assume that the use of crimped diaphragms will reduce the temperature error to one-third, since the displacement of a crimped diaphragm can be considered equivalent to the movement of a piston and not a cone.

In measurements with a hydraulic distance gauge other errors can also arise due to the expansion of the vessel and the tube, but experience has shown that they are negligibly small.

Construction of a hydraulic distance gauge. On the basis of above analysis and investigations the author developed a new instrument with the following parameters (Table 2).

The hydraulic distance gauge (Figs. 2 and 3) consists of a vessel mounted on a bracket of a normal stand with a screw thread. The distance gauge consists of a body 1, inside which there is a diaphragm 2, pressed against the body of a rubber ring 3; the hermetic sealing is achieved by compressing the diaphragm between the body of the instrument and the guiding bushing 4. The body contains tinted water; the pressure of rod 5, which is guided by bushing 4, against the diaphragm forces the water into the glass tube 6, placed inside a graduated tube 7. Tube 6 is fixed to body 1 of the instrument by flange 8.

TABLE 2

Parameter	Instrument types		
	No. 1	No. 2	No. 3
Calibrations, mm	0.002	0.005	0.005
Range, mm	± 0.060	± 0.150	± 0.150
Graduation size, mm	1.0	1.0	5.55
Number of graduations	60	60	60
Scale length, mm	60.0	60.0	330.0
Internal diameter of the tube, mm	2.5	3.0	3.0
Internal diameter of the vessel, mm	100.0	73.5	100.0
Overall height of the instrument, mm	229.0	229.0	503.0
Length of the glass tube, mm	140.0	140.0	410.0
Transfer ratio	500	200	370

The displacement of water in the tube (zero setting) is accomplished by turning screw head 9 which revolves in a nut 10 sweated onto the body of the instrument. The bottom of the nut rests on a rubber packing which prevents any water flowing out of the vessel.

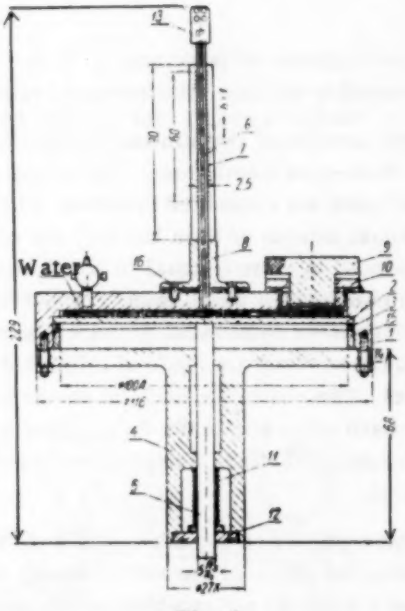


Fig. 2

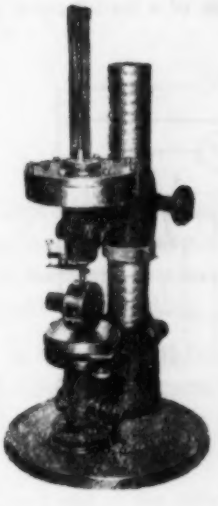


Fig. 3

The measuring rod 5 is returned back to normal by means of spring 11 and centered in its lower part by washer 12, which for convenience of assembly is screwed into the guiding bushing 4.

In order to prevent the liquid (water) evaporating, the glass tube is covered by a rubber cap 13 with air holes in it.

The guiding bushing 4 is screwed to the body of the instrument by two bolts 14; it presses against ring 15, which in turn presses against the rubber ring 3. An air outlet from the instrument chamber is provided by a breather tap 16.

The measurements on this instrument are made in the normal comparative manner, similarly to a distance gauge or a vertical telescope caliper.

The instrument was tested at the All-Union Technological Design Institute of Heavy Engineering and found satisfactory; its total error did not exceed that of a wide-scale precision distance gauge with a similar calibration.

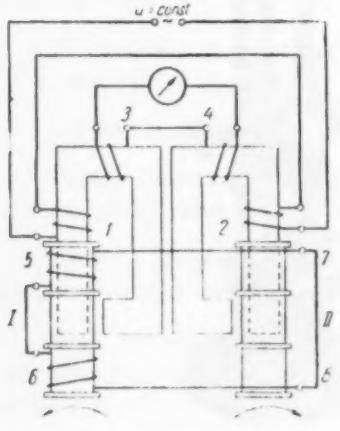
The instrument described above proves the possibility of using the hydraulic method for linear measurements and the production of commercial instruments operating on this principle and capable of wide application in different devices, including those used in various methods of automatic control.

REMOTE MEASUREMENTS OF LARGE DISPLACEMENT ANGLES

A. D. Barinberg

The characteristic of the majority of potentiometer, selsyn, capacitance, inductance, or photoelectric transducers which measure displacement angles is such that variation of the electrical parameters in the required limits is possible as a maximum over one full revolution, which can correspond to any number of revolutions of the mechanism. The intermediate transmission lowers considerably the accuracy of measurements and hinders the use of the output variable for automation purposes.

The proposed new type of transducer [1] intended for remote measurement of large angular displacements is based on the use of a transformer whose secondary winding has a smoothly variable transformation ratio.



The transducer (see figure) consists of two similar double-core transformers with open cores or one three-core transformer. The primary windings 1 and 2 with an equal number of turns are connected in series. The secondary windings 3 and 4 also have an equal number of turns but they are connected in opposition. The total emf induced in them is equal to zero. Windings 5, 6, 7, and 8 are wound on formers I and II which revolve round the transformer cores. The former consist of cylindrical drums whose surfaces have helical grooves cut in them. The windings are made of a flexible conductor which fits into the grooves. The drums are made of an insulator and connected mechanically to each other and to the drive whose angle of revolution it is required to determine. Windings 5 and 7 cover the core, but windings 6 and 8 are outside it.

The revolution of the formers provides a smooth variation of the transformation ratio. At first, when the whole of the wire is wound on former I, the current induced in winding 5 produces a flux which in turn induces an emf in winding 3. The instrument reading is now at its maximum. In the course of rewinding, an emf is induced in coil 7 in the same direction as that of coil 5. Since the total number of turns in the two coils is the same, the current in the circuit of coils 5, 6, 7, and 8 remains constant. The emf in coils 3 and 4 changes proportionately to the variation of the number of turns in windings 5 and 7. The difference of the emfs in coils 3 and 4 registered by the instrument is a function of the angle of revolution. This difference is zero when the number of turns in winding 5 and 7 is the same. Coils 6 and 8, which are placed outside the cores, serve to complete the secondary circuit without any contacts. The absence of sliding contacts raises the reliability of the transducer operation.

Certain constructional peculiarities of the transducer should be noted. The change in the output variable from the maximum to zero is attained by rewinding half the winding 5 onto former II; it is therefore unnecessary

to place half the windings into the groove. It is sufficient to wind them in several layers onto a small portion of former I. It is desirable to have a minimum gap in the cores. The number of turns in the primary and output windings depends on the given input and output quantities; the number of turns in the secondary windings depends on the angle to be measured and the measuring scale required. The permissible speed of rotation and the accuracy of operation of the transducer depend to a great extent on the parallelism and symmetry of formers I and II. The absence of voltage or a break in the circuit are registered by the measuring instrument, since a current flows constantly through all the windings.

It should be remembered when operating the transducer that the linear relation of the rotation angle holds with respect to the emf and not the measured voltage. Loading considerably distorts this relationship. The presence of air gaps and a shorted winding makes an increase in the transformer power ineffective. It is more expedient to measure by means of a balancing method or with an instrument that has a high input impedance, and, if necessary, an amplifier.

The transducer can also be used for measuring small angular displacements if it is required to obtain a continuous variation of the output variable over a wide range. For this purpose, a reduction gear with a large gear ratio will be required, since a large angular displacement of the transducer formers must correspond to a small rotation angle of the driving shaft.

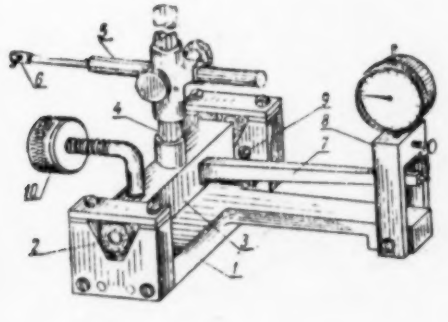
LITERATURE CITED

[1] A. D. Barinberg, Author's Certificate No. 120,562 dated January 28, 1958.

MEASUREMENT OF DIMENSIONS IN INACCESSIBLE PLACES

I. A. Kuptsov

The universal lever instrument with an extensometer (see figure) developed by us is being widely used in measuring the deviation of holes from a common axis, the thickness of walls at a considerable depth in small holes, the direction of teeth and internal grooves of small diameters, and other similar dimensions.



A rectangular axle 3 is fixed on ball bearings 2 in V-shaped supports of body 1 of the instrument. A tube 4 which is 16 mm in diameter and 500 mm long is screwed into the axle.

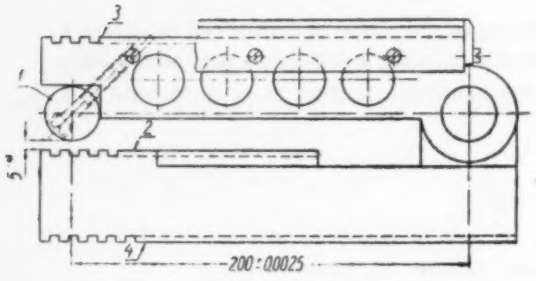
Holder 5, which can be fixed to the tube at various heights, carries at its end an exchangeable tip 6. Lever 7 which is 150 mm long is fixed to axle 3. The extensometer fixed in a П-shaped bracket 8 rests with its tip on the end of lever 7. The rotation of axle 3 in its bearings is limited by two stop screws 9. The measuring effort of tip 6 is adjusted by means of weight 10 which can be freely displaced along the threaded L-shaped hook, screwed into axle 3 in such a manner that it can be easily rotated.

MEASUREMENT OF SMALL ANGLES

V. I. Nikolaev

The hinged sine rules made at present according to GOST 4046-48 are in practice useless for measuring angles smaller than 10', since for this purpose block gauges smaller than 0.5 mm would have to be used. Hence small angles are usually measured on a simple sine rule by a difference between two block gauges; this procedure is cumbersome and unstable.

In order to avoid these defects we have slightly changed the construction of hinged sine rules.



In the standard version of the rule, its roller 1 (see figure) touches in the zero position the upper surface 2 of the base. In the new construction a gap of 5-10 mm is left between roller 1 and surface 2.

By placing block gauges under the roller after the rule has been assembled, the size of the gap is accurately determined and its value is always added to the measurements.

This constructional modification makes it possible to measure any small angles.

It is desirable that in the manufacture of rules of this type the gap between roller 1 and surface 2 be made equal to a whole number of millimeters, thus making the calculation of the measured distance easier. It is easy to obtain this gap by lapping and polishing surface 2.

In order to facilitate the polishing of large surfaces 2, 3, and 4, they should be grooved. This will not only facilitate the finishing of accurate surfaces, but will also improve their operational properties.

When grooved surfaces are moved over a flat plate or a component is moved over these surfaces, dirt and other extraneous matter is gathered in the grooves and is easily removed by washing.

CONTROLLING THE CURVATURE OF THREAD GAUGES

N. M. Zhuravlev

In order to ensure interchangeability of screwed connections, they are controlled by means of thread gauges which have not only a specified mean diameter, but also a specified pitch and half the thread angle, i.e., all the elements affecting the interchangeability of threads. For first-grade screw threads, it is recommended to select thread gauges in such a manner that the sum of the actual deviations of screw pitch, half the thread angle, and mean diameter do not exceed 50-70% of the sum of tolerances for these elements. This limitation of the actual deviations of the screw thread elements is introduced for decreasing the effect of gauge errors on the relatively strict tolerances of first grade and more accurate screw threads.

However, despite the strict tolerances and the limitation of the actual deviations of the screw thread elements, when they are checked by means of thread gauges, contradictory results are often obtained. Thus a tapped hole will engage with one thread gauge, but not with another similar gauge. It has also happened that

in checking ring gauges PR against two identical-in-size thread gauges U-PR, the ring gauge would fit one but not the other thread gauge.

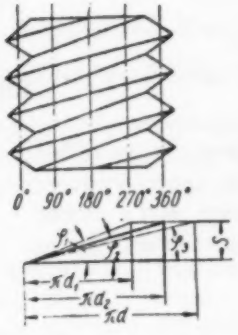


Fig. 1

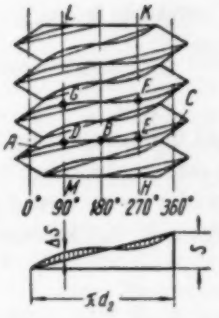


Fig. 2

When checking the production of an automatic machine at the "Kalibr" plant by means of thread gauges, it was found that despite the fact that two thread gauges had the same mean diameter and were specially selected to have minimum deviations in their pitch and half their thread angle, one of them passed and the other rejected the tested articles. An analysis of the characteristics of these gauges showed that they had different thread curvatures, which was the reason for their discrepancy in testing threads.

Figure 1 shows a thread which has a constant helix angle φ_2 (the angle formed by the screw line and a plane perpendicular to the axis of the thread).

The helix angle is a function of the mean diameter of the thread:

$$\operatorname{tg}\varphi_2 = \frac{S}{\pi d_2}, \qquad (1)$$

where S is the thread pitch; and
d_2 is the mean diameter.

Figure 2 shows a thread with a curvature and a helix angle which changes over one turn; thus points A, B, and C corresponding on the thread to 0°, 180°, and 360° have a nominal helix angle, whereas point D at 90° has an angle larger than the nominal, and point E at 270° an angle smaller than the nominal. Formula (1) shows the relation of the helix angle to the pitch and the diameter.

Figure 1 shows the variation of the helix angle (φ_1, φ_2, φ) with respect to the diameter (d_1, d_2, d), where d is the external and d_1 the internal diameters of the thread. In this instance there is no curvature in the thread. If, however, there is a deviation of the helix angle from a regular screw line due to errors in the thread pitch ΔS (Fig. 2) over one thread turn, there will be a thread curvature, which is commonly known as a "drunken" thread.

Although this defect of the thread is the result of an error in the pitch, it cannot be checked by the normal means used for controlling the pitch. In fact, if the pitch is checked along section LM or KH (Fig. 2) where the largest deviation of the pitch exists, the dimension DG will be equal to EF and thus, no matter where the pitch is checked the distance between the parallel sides of the turns will remain equal in any section.

Compensation of the thread curvature. Figure 3 shows a go thread gauge with a curved thread screwed into an article. It will be seen that in order to make the gauge screw into the article, it is necessary to compensate for curvature by either decreasing the mean diameter of the gauge or increasing the mean diameter of the article. The operator is obliged to take the latter course and approach the mean diameter of the article to the no-go gauge.

The required increase of the mean diameter of the article (the diameter compensation of the thread curvature f_n) is determined from the sketch in Fig. 3: $f_n = d'_2 - d_2$.

$$\frac{1}{2} f_n = \frac{1}{2} \delta_n \cot \frac{\alpha}{2},$$

or

$$f_n = \delta_n \cot \frac{\alpha}{2}, \qquad (2)$$

where δ_n is the limiting deviation of the thread curvature; and

$\frac{\alpha}{2}$ is half the thread angle.

For a metric thread the diameter compensation of the thread curvature is

$$f_n = 1.732\,\delta_n. \qquad (3)$$

Hence the dimension of a go thread gauge with a curved thread is equivalent to a larger gauge with a straight thread. The use of such a gauge is disadvantageous since it reduces the tolerances, lowers the labor productivity, and increases the percentage of rejects. The dimension of a no-go thread gauge with a curved thread is equivalent to a larger size of a straight gauge. Such a gauge must not be used since it will pass as good, articles which should be rejected.

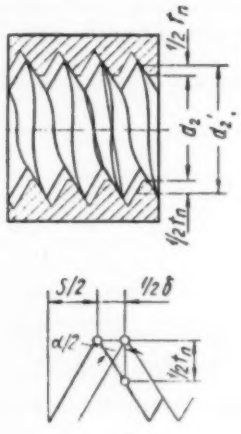


Fig. 3

In small-scale mass production this difficulty is overcome in the main by exchanging gauges for more accurate ones or by a more accurate thread cutting (with stricter manufacturing tolerances), whereas in large-scale

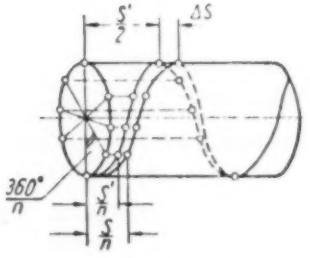


Fig. 4

mass-production, especially with automatic control, a more precise checking of threads by means of gauges is required. Therefore, it is not by accident that the main difficulty in making thread gauges for automatic machines consists in obtaining gauges without curved threads.

Checking of gauges in the Bureau of Interchangeability Laboratory and at the "Kalibr" plant showed that thread curvatures sometimes exceeded the pitch tolerance deviation.

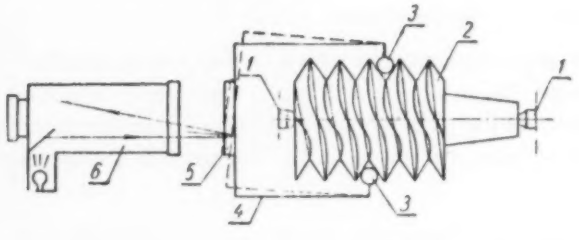


Fig. 5

The existing standards for thread gauges do not specify tolerances for thread curvature, presumably assuming that the pitch tolerance covers thread curvature. Sometimes the words "curvature" or "drunken" threads are considered to be nominal. Sometimes a slanting thread is called "drunken" when its left-hand $\frac{\alpha}{2}$ is not equal to the right-hand one. Taking into account that the diameter compensation of the thread curvature is considerable [see (3)] and the definitions of thread curvature vary, it is essential that the standards for the thread gauges should both define thread curvature and provide tolerances for it.

It is known that worn equipment, defective centering, etc., are the causes of thread curvature. It is therefore necessary to check the machine tools for these defects as well as for the accuracy of pitch.

Thread curvature checking. Normally, the thread curvature of gauges is checked on a universal microscope by means of a measuring head (IB-21). The thread gauge is fixed in pointed journals and connected to the measuring head by means of a clip; measuring blades are placed to either side of the thread profile and the initial reading taken on the millimeter scale of the instrument's longitudinal travel. The degree scale of the

measuring head it set to zero; the thread gauge is then turned through a given angle and the image of the left and right thread profile are made to coincide, by moving the microscope stage longitudinally, with the ocular line image of the goniometric head, and appropriate readings are taken. The difference between the actual dimension $\frac{S}{n}$ (Fig. 4) and the calculated one $\frac{S'}{n}$ represents the error of the pitch at its $\frac{1}{n}$ portion, (where n is the number of portions of one turn at which measurements are made, for instance, 8). Next by turning the measuring head consecutively through $2\frac{360^\circ}{n}$; $3\frac{360^\circ}{n}$ ... $n\frac{360^\circ}{n}$, dimensions $2\frac{S}{n}$; $3\frac{S}{n}$ ... S, respectively, are determined. The difference between the measured dimensions of thread intervals and the calculated ones provides the value of the pitch error. The difference between the largest positive and the largest negative error determines the curvature of the thread.

The checking of the thread curvature on a universal microscope is complicated and laborious, taking an experienced operator at least one hour to carry out, whereas the cutting of such a thread would only occupy a few minutes of a mechanic's time. Moreover, in order to determine the maximum pitch error over one turn, it is necessary to measure the thread continuously, whereas only discrete fractional values of pitch are measured under the microscope.

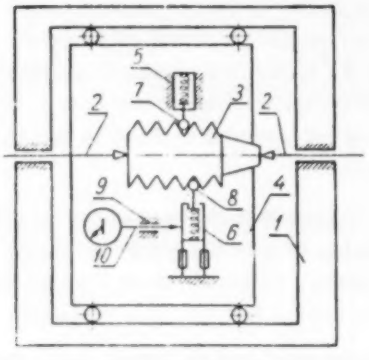


Fig. 6

It is also possible to determine the curvature of the thread in the following manner. The gauge is fixed in the journals of a universal or measuring microscope and the image of the goniometric-head profile-line is made to coincide first with one-half of the root of the thread on one side, and then, by a transverse movement of the stage, on the other side. The value of the deviation (ΔS) of the root of thread from the profile line in the second measurement represents the deviation of the pitch over half a thread turn at the given section. By changing the position of the gauge, the maximum deviation is found, which represents the thread curvature. This method is inaccurate and can only be used for large curvature tolerances.

The thread curvature can be checked with sufficient accuracy by means of an autocollimator (Fig. 5). Thread gauge 2 is fixed in journals 1, and ball tips 3, which are made to fit into the thread grooves of the gauge, are connected to a common frame 4 with a mirror 5. The gauge is turned by hand and the displacement of the mirror frame observed through collimator 6. If the thread is curved, the mirror frame will, in addition to its forward movement along the thread axis, also oscillate as shown in Fig. 5 by a dotted line. This displacement is registered on the drum of the recording device of the autocollimator, and with an appropriate conversion determines the thread curvature.

A new instrument for determining the curvature of thread gauges. The Interchangeability Bureau has produced a model of an instrument which provides a relatively simple and convenient determination of this curvature (Fig. 6). Base 1 of the instrument carries journals 2, into which the tested gauge 3 is fixed. Carriage 4, which moves freely on ball bearings, carries a fixed stand 5 and a spring parallelogram 6 with spring tips 7 and 8. An extensometer with calibrations of 0.001 mm is mounted on stand 9 and rests with its measuring tip on the spring parallelogram. When the gauge is rotated about the journals, carriage 4 is moved forward together with the extensometer along the axis of the thread gauge by means of the fixed tip 7 and stand 5. If the gauge has no thread curvature, the extensometer pointer will remain stationary; if there is a curvature, the pointer will be displaced and its maximum deviation to the left or right will determine the value of the curvature. This check can be carried out in 1 min. The instrument provides facilities for registering the thread curvature on a normal electric induction recorder type BV-662 or a pneumatic recorder.

SUMMARY

The checking of threads in commodities, including automatic checking, by means of thread gauges, is greatly affected by the thread curvature of these gauges. For checking the thread curvature of such gauges a new instrument is proposed which combines high productivity with great precision.

CHECKING LOW-MODULE GEARS

I. M. Efune

As the worm cutter becomes worn in gear cutting, the thickness of gear teeth, gears, and segments alters, thus requiring a hundred percent inspection.

The most accurate method of indirectly estimating the thickness of teeth is by measuring dimension M with the aid of rods (Fig. 1). The measurement of this distance by means of a micrometer with the aid of rods is unproductive and inaccurate, due to the lack of precision in placing the detail in the micrometer, especially in the case of thin and screw gears.

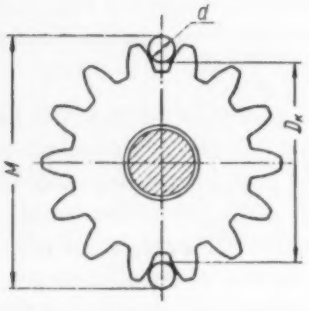


Fig. 1

These defects are eliminated in an indicating device in which the tested detail is fixed on a movable spindle in a definite position between the measuring rods (Fig. 2). The instrument body 1 carries a carriage 2 on three supports, each of which consists of three balls. The movement of carriage 2 is limited by two stop screws 3 and its removal is prevented by two pins 4. Carriage 2 has five fixing holes for mounting, in any of them, spindle 5, and five tapped holes on the sides for securing the spindle by means of a screw, thus providing a firm support for gauge 6 or the tested details which are mounted on the spindle. Mandrel 7 and an extensometer are screwed to the body 1 of the instrument. Jaws 9 which have measuring rods secured to them by screws are fixed to mandrel 7 and extensometer socket 8.

The device is set by placing gauge 6 on spindle 5 at the required height. The extensometer stem is approached to gauge 6 and the pressure of the stem spring against the gauge pushes it, spindle 5, and carriage 2 until the gauge touches the measuring rod on the other side. When the gauge touches the two opposite measuring rods, the extensometer is set to zero.

In mass production testing the extensometer stem is withdrawn, the gauge removed, and the detail under test fixed in its place on spindle 5. The stem is then again approached until the measuring rods enter the grooves of the detail under test. The quality of the detail is determined by the deviation of the extensometer needle from the setting obtained in its calibration by means of the gauge.

The nominal value of dimension D_k of the gauge (Fig. 1) is calculated from formula $D_k = M - 2d$, where M is the nominal dimension between rods, and d is the nominal diameter of the measuring rods.

The upper deviation and tolerance according to the grade of accuracy and the nature of gearing are marked on the gauges. If, however, the gauge has a deviation from the nominal value exceeding 0.003 mm, it is marked with its actual size and the tolerances are corrected for the difference between the nominal and the actual sizes of the gauge. The checking is then carried out against the markings on the gauges.

In order to compensate for the possible displacement of the gear ring axis with respect to the plane of the measuring rods, the seating diameter of spindle 5 (Fig. 2) is made 0.2 mm smaller than the diameter of the opening in the detail, and the gauge is placed on spindle 5 according to the sliding seating of second grade precision. For checking gears with an uneven number of teeth the seating diameter of spindle 5 is made small enough not to fit into the gear opening but to serve as a guide for the measuring rods to engage with the appropriate grooves in the gear wheel.

For checking dimension M in pinions, spindle 5 (Fig. 2) is made with a hole into which the shank or intermediate pivot of the pinion is loosely fitted. The protruding external diameter of spindle 5, obviously, must not touch the measuring rods. In this case, spindle 5 serves to guide the position of the pinion axis. Its accurate positioning is achieved when it is pressed between the two measuring rods during measurements. The gauge has approximately the same shape as the pinion, but its seating diameter slides into the spindle hole according to a second grade fit, and the external diameter of the gauge which engages with the measuring rods is calculated from the formula $D_k = M - 2d$.

The gear quadrants are checked by means of socket 8 with its measuring rod. Mandrel 7 is then withdrawn and carriage 2 fixed by means of screws. Gauge 6 also calculated from formula $D_k = M - 2d$ is fixed onto spindle 5 in order to set the extensometer to zero. The checking with one rod should be carried out in the middle and extreme positions of the gear ring and then the dimension calculated as the arithmetic mean of the extensometer readings, since in this instance spindle 5 is not floating and the run-out of the gear ring affects the extensometer readings.

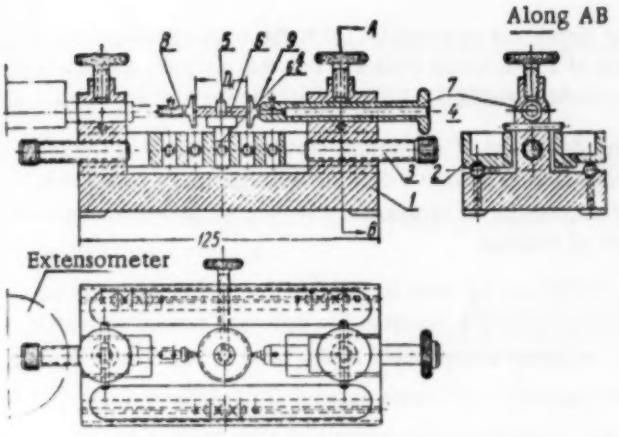


Fig. 2

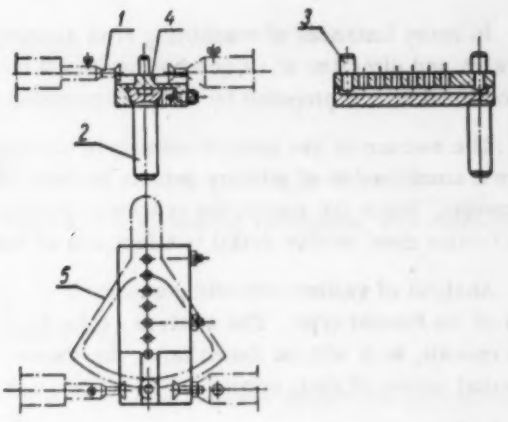


Fig. 3

The checking of the gears' external diameter and the gear quadrants' external radius is carried out in a manner similar to that of checking dimension M, but the gauges are made to correspond to the nominal external diameters of the details to be checked, have a tolerance of ± 0.003 mm, and instead of the extensions with measuring rods, use flat extensions.

For the purpose of checking dimension L_n against a general standard, instead of extensions with measuring rods, conical extensions 1 are fixed in the extensometer socket and the mandrel (Fig. 3). Instead of the spindle, stem 2 of the table is mounted at the appropriate height in a fixing hole of the carriage. A gauge, placed on the first index pin 3 which is fixed to saddle 4 in line with the stem axis, has an external diameter equal to the nominal value of L_n with a tolerance of ± 0.003 mm and serves to set the extensometer to zero. A second index pin 3 is placed in another fixing hole of saddle 4 to carry quadrant 5 or a gear to be checked. After the extensometer has been set to zero, the detail is approached to the conical extensions until they touch the profile butts. The extensometer deviation from the normal dimension L_n determines the quality of the detail under test.

An accurate placing of the detail when dimension L_n is checked is achieved owing to the displacement of the carriage and the resting of the detail on the plane of saddle 4, which is perpendicular to the shanks of extensions 1. The setting of the extensometer to a given number of teeth by dimension L_n is achieved by means of a tentative placing of a guard lug at the top of the extensometer stem. In this operation, the carriage movement, which is controlled by stop screws, must be small.

It should be noted that the checking of dimension M by means of measuring rods eliminates the necessity of measuring the total standard L_n, and the question of which is more expedient to measure should be decided for each particular case.

The error of measurement is equal to that of the extensometer over small ranges; the duration of each test is about 3 seconds.

EVALUATION OF CIRCULAR COMPONENTS BY THE HARMONIC ANALYSIS METHOD

M. S. Mirkin

In many instances of machining error analysis, it is important to establish from the total measured error the value and direction of its components in all the points of a machined surface. For this purpose, the method of functional errors, proposed by N. A. Kalashnikov, L. A. Arkhangel'skii, Yu. N. Lyandon et al., has been used.

The essence of the method consists in expressing the deviation of the actual surface from a given shape due to a combination of primary defects in terms of a functional relation to definite kinematic or geometric parameters. Since the machining process is periodic and consists of a complete cycle, the variation of the error of a circular cross section detail is a function of the angle of rotation.

Analysis of various periodic processes is usually carried out by their expansion into trigonometrical series of the Fourier type. The analysis of the error by means of such a function has not only a nominal value, but it reveals, as it will be shown later, the sources of the separate components of the total error, thus reflecting the actual nature of their origin.

In this article, the values of the series' terms and their amplitude are examined with respect to the measurement basis adopted.

The error of a circular component cross-section dimension is represented by the difference between the given and the actual values of the component's radius:

$$\Delta r = r_0 - r, \tag{1}$$

where r_0 is the given (nominal) value of the radius; and
r is the actual value of the radius.

The functional expression for the radius error can be represented in the form:

$$\delta r = f(\varphi),$$

where φ is the deflection angle of the detail.

The functional expression for the radius error can be represented in the form:

$$\delta r = \frac{a_0}{2} + \sum_{\kappa=1}^{n} r_\kappa \sin(\kappa\varphi + \varphi_\kappa) \tag{2}$$

or

$$\delta r = \frac{a_0}{2} + \sum_{\kappa=1}^{n} (a_\kappa \cos\kappa\varphi + b_\kappa \sin\kappa\varphi). \tag{3}$$

Let us examine the significance of various terms of the series.

The constant term of the series $-(a_0/2)$. If the radius error is a constant in the limits of the cross-section circle, then $a_k = b_k = 0$. Hence, δr does not depend on the angle of rotation or the initial phase. It is obvious that for this particular component $\frac{a_0}{2}$ represents a machine tool setting error, as the result of which the radius of the finished component differs from the required value.

The first term of the series (k = 1) is the fundamental with a period of T = 2π. It is easy to see that this term represents the displacement of the rotation axis of the component with respect to its geometrical axis, i.e., its eccentricity. Let O be the geometrical axis of the component (Fig. 1), O_1 its axis of rotation, and e the amount of eccentricity.

From the cosine theorem we have:

$$r_0^2=r_1^2+e^2-2r_1e\sin\varphi_1,$$

where φ_1 is the angle between the radius and the origin of coordinates.

Neglecting e^2 as a second order quantity, we have

$$r_1-r_0\simeq e\sin\varphi_1.$$

When the component is turned through angle φ the readings of the measuring instrument will correspond to the difference $r - r_1$:

$$\delta r=r-r_1=r_0+e\sin(\varphi+\varphi_1)-$$
$$-(r_0+e\sin\varphi_1)=-e\sin\varphi_1+e\sin(\varphi+\varphi_1). \qquad (4)$$

It is obvious that (4) is represented by a constant term $\frac{a_0}{2} = -e\sin\varphi_1$, whose magnitude depends on the origin from which angle φ_1 is measured, and by the first term $r_1 \sin(\varphi + \varphi_1)$ whose amplitude is equal to the eccentricity $r_1 = e$.

Second term of the series (k = 2) contains the second harmonic with a period T = π; hence, the curve which represents this defect in the shape of the cross section will have two maxima and two minima for each cycle of 2π. This corresponds to an elliptical or oval shape or any other defect which produces two maxima and two minima during measurement.

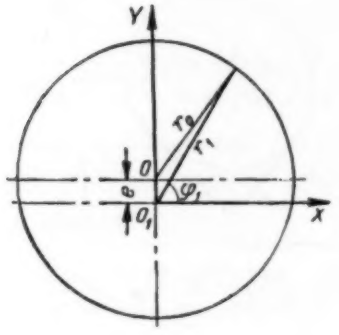


Fig. 1

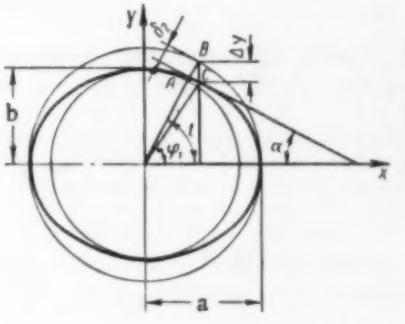


Fig. 2

Determining ellipticity when the component is measured between journals. The parametric equation of an ellipse has the form:

$$x=a\cos t;\quad y=b\sin t.$$

Let us denote by φ_1 the angle between the radius-vector ρ and the X-axis (Fig. 2), then:

$$x=\rho\cos\varphi_1;\ y=\rho\sin\varphi_1.$$

When components with a small degree of ellipticity are measured, which is usually the case in engineering, it is possible to write approximately:

$$\sin\varphi_1 \simeq \sin t \;\&\; \operatorname{tg}\alpha \simeq -\operatorname{tg} t.$$

From triangle ABC, we have

$$\Delta y = a\sin t - b\sin t = (a-b)\sin t \simeq (a-b)\sin\varphi_1;$$
$$\delta r = AB = \Delta y \sin t = (a-b)\sin^2 t \simeq (a-b)\sin^2\varphi_1.$$

When the component is rotated through angle φ the readings of the measuring instrument will correspond to:

$$\delta r = (a-b)\sin^2(\varphi+\varphi_1) - (a-b)\sin^2\varphi_1.$$

Denoting $2\varphi_1 + \frac{3\pi}{2} = \varphi_2$, we have

$$\delta r = -\frac{a-b}{2}\sin\varphi_2 + \frac{a-b}{2}\sin(2\varphi+\varphi_2). \qquad (5)$$

It follows from (5) that an error in the shape of a component with an elliptical cross section, when measured by rotating it about an axis which passes through the center of the ellipse, can be expressed by a Fourier series with a constant term related to the reference line from which angle φ_2 is measured and a second harmonic whose amplitude is equal to half the difference of the axes of the ellipse (Fig. 3).

Determining ellipticity when the component is measured in a V-block. Often ellipticity is measured by placing the component in a V-block and rotating it under a measuring tip. In this case the V angle affects the results.

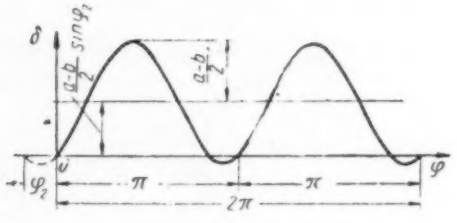


Fig. 3

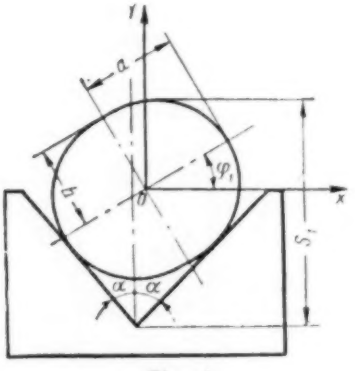


Fig. 4

Let us use a system of coordinates which pass through the center of the ellipse; and let us examine a general case when axis OY does not coincide with the bisector of the V angle, but remains parallel to it (Fig. 4). This occurs when measurements are made with an instrument which has a flat end.

Let us denote by φ_1 the angle between axis OX and the major axis of the ellipse; in this measurement the instrument readings will vary according to the distance S_1, which is determined by angle φ_1 and 2α. Berndt [1] derived for this case the following relationship:

$$S_1 = \frac{a+b}{2}\left(\frac{1}{\sin\alpha}+1\right) + \frac{a-b}{2}\left(\frac{\cos 2\alpha}{\sin\alpha} - 1\right)\cos 2\varphi_1, \qquad (6)$$

where α is half the V angle.

When the component is turned through angle φ with respect to the reference line from which φ_1 is measured, we shall have:

$$\delta r = S_1' - S_1 = \frac{a-b}{2}\left(\frac{\cos 2\alpha}{\sin\alpha} - 1\right)\cos(2\varphi + 2\varphi_1) -$$
$$- \frac{a-b}{2}\left(\frac{\cos 2\alpha}{\sin\alpha} - 1\right)\cos 2\varphi_1.$$

Denoting as we have done before $2\varphi_1 + \frac{3\pi}{2} = \varphi_2$, we shall obtain:

$$\delta r = -\frac{a-b}{2}\left(1 - \frac{\cos 2\alpha}{\sin\alpha}\right)\sin\varphi_2 +$$
$$+ \frac{a-b}{2}\left(1 - \frac{\cos 2\alpha}{\sin\alpha}\right)\sin(2\varphi + \varphi_2). \qquad (7)$$

Expression (7) is similar to (5), the only difference being that when measurements are made in a V-block an additional factor $\left(1 - \frac{\cos 2\alpha}{\sin\alpha}\right)$ appears, which depends on the V angle and affects the amplitude of the second harmonic.

In order to eliminate the effect of the V-block angle, it is necessary to make it such that $\frac{\cos 2\alpha}{\sin\alpha} = 0$, i.e., $\cos 2\alpha = 0$; $2\alpha = 90°$.

Hence, if the angle of the V-block is $2\alpha = 90°$ it does not affect the measurements. From (7) it follows that for $2\alpha = 60°$, $\delta r = 0$, i.e., the readings of the measuring instrument will approach zero. It is obvious that such a V-block is unsuitable for technical measurements.

When ellipticity is measured on a table which is flat, $2\alpha = 180°$, the amplitude of the second harmonic is equal to $(a - b)$.

Third term of the series ($k = 3$). The curve representing this defect in shape will have three maxima and three minima in a cycle of 2π and will be represented by a third harmonic with a period of $2\pi/3$.

In production conditions such a curve normally represents faceting obtained with centerless grinding or is due to the deformation of the component when it is fitted.

Let us examine a few cases.

Measurements made with the component fixed in journals. The outline is represented by a closed contour consisting of three arcs, which are described by radius d from the three apexes of an equilateral triangle with a side d (Fig. 5).

Let us construct a system of coordinates XOY from the center of the circle.

The coordinates of point M (XY) will be:

$$x = r_1\cos\varphi; \quad y = r_1\sin\varphi.$$

Let us construct a new system of coordinates $X_1O_1Y_1$. In the new system point $M(X_1Y_1)$ will be expressed by:

$$x_1 = x + a; \quad y_1 = y + b.$$

From triangle O_1OB, we have: $a = \frac{d}{2}\,\mathrm{tg}\,30° = \frac{\sqrt{3}}{6}\,d$; $b = \frac{d}{2}$.

At the same time $x_1 = d\cos\alpha$; $y_1 = d\sin\alpha$; hence:

$$d\cos\alpha = r\cos\varphi + \frac{\sqrt{3}}{6}d;\quad d\sin\alpha = r\sin\varphi + \frac{d}{2}$$

By squaring both equations and adding them together, we obtain:

$$r = -\frac{d}{\sqrt{3}}\sin\left(\varphi + \frac{\pi}{6}\right) + \frac{d}{\sqrt{3}}\sqrt{2 + \sin^2\left(\varphi + \frac{\pi}{6}\right)}.$$

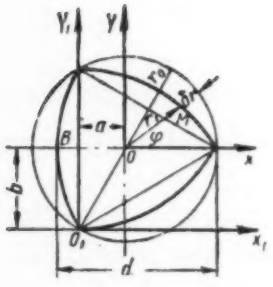


Fig. 5

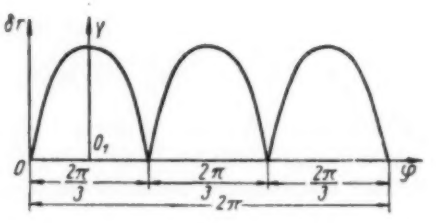


Fig. 6

Developing the root into a series and taking the first two terms, we obtain the error of the shape as determined by the measuring instrument readings:

$$\delta r = \frac{8 - 9\sqrt{2}}{8\sqrt{3}}d + \frac{d}{\sqrt{3}}\left[\frac{\sqrt{2}}{8}\cos\left(2\varphi + \frac{\pi}{6}\right) + \sin\left(\varphi + \frac{\pi}{6}\right)\right]. \tag{8}$$

Since the contour of the outline has been described from three different points, placed at an angle of 120°, Eq. (8) only holds for the range of $0 < \varphi < \frac{2}{3}\pi$.

It is obvious that for the range of $\frac{2}{3}\pi < \varphi < \frac{4}{3}\pi$ Eq. (8) will assume the form:

$$\delta r = \frac{8 - 9\sqrt{2}}{8\sqrt{3}}d - \frac{d}{\sqrt{3}}\left(\frac{\sqrt{2}}{8}\cos 2\varphi + \cos\varphi\right), \tag{9}$$

and for the range $\frac{4}{3}\pi < \varphi < 2\pi$:

$$\delta r = \frac{8 - 9\sqrt{2}}{8\sqrt{3}}d + \frac{d}{\sqrt{3}}\left[\frac{\sqrt{2}}{8}\cos\left(2\varphi - \frac{\pi}{3}\right) + \cos\left(\varphi + \frac{\pi}{3}\right)\right]. \tag{10}$$

Figure 6 represents a curve of function $\delta r = f(\varphi)$. The function has a period of $T = \frac{2\pi}{3}$ with maxima at 60°, 180°, and 300°, equal to

$$\delta r_{max} = \frac{2-\sqrt{3}}{\sqrt{3}} d = 0.154\ d. \tag{11}$$

Measurement of faceting in a V-block. This case is dealt with in [1]; the relationships for the two extreme positions are obtained at which the apexes of the outline coincide with the symmetry line of the V-block (Figs. 7a and 7b).

For a V-block with an angle $2\alpha_1 < 120°$

$$\delta r_{max} = S_1'' - S_1' = \left[\left(\sqrt{3} - 1 \right) - \cot \frac{\alpha_1}{2} \right] d =$$

$$= \left(0.732 - \cot \frac{\alpha_1}{2} \right) d. \tag{12}$$

For a V-block with an angle $2\alpha_1 > 120°$

$$\delta r_{max} = \left(\frac{1}{\sin \alpha_1} - 1 \right) d. \tag{13}$$

For a V-block with an angle $2\alpha_1 = 120°$

$$\delta r_{max} = \frac{2-\sqrt{3}}{\sqrt{3}} d = 0.154 d. \tag{14}$$

Equation (14) coincides with (11), hence when faceting is measured in a V-block with an angle $2\alpha_1 = 120°$, the angle does not affect the results.

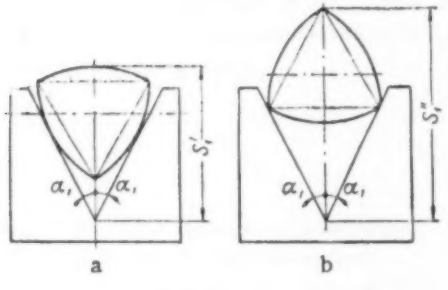


Fig. 7

When faceting is measured on a plane ($2\alpha_1 = 180°$) the readings of the measuring instrument will be equal to zero, according to Eq. (13) (i.e., the faceting does not become apparent).

An analysis of these formulas shows that for a clearer observation of faceting, measurements should be made with as sharp a V-block angle as possible.

The curves which represent the deviation from a circular shape due to faceting have a period of $\frac{2\pi}{3}$, and consist of third harmonics.

Remaining terms of the series. It is obvious that the fourth term of the series represents an error which has four maxima and minima during one cycle of 2π, i.e., it represents a tendency to a square shape, the fifth term a tendency to a pentagon shape, etc.

This analysis shows that in developing the functional error each term of the Fourier series represents a definite component of the total error. Thus, the error expressed by the first term represents eccentricity; the remaining terms represent the deviations of the cross-sectional shape from a circle.

The total of these errors, i.e., their sum:

$$\delta r = \frac{a_0}{2} + \sum_{\kappa=1}^{n} (a_\kappa \cos \kappa\varphi + b_\kappa \sin \kappa\varphi).$$

represents the total error of machining. Moreover, the constant term $\frac{a_0}{2}$ is equal to the mean value of this error.

In analyzing the measurement results, it is possible, in the majority of cases, to take the three first terms only, which express the total error sufficiently accurately for all practical purposes.

The actual component has not a clearly expressed form of an ellipse, oval, or a triangular outline which completely corresponds to the above analytical relations. In fact, ellipticity or ovality represent a deformation of the shape which produces two maxima and two minima in measurements, and faceting represents a deformation which produces n maxima and n minima. Practical methods of harmonic analysis provide, however, the finding from the measurement results, for each concrete component, of the characteristics which we have called ellipticity, faceting, etc.

It will be seen from the above expressions that the total error within the limits of the cross section depends not only on the amplitude of the error components, but also on their initial phases. In this connection, the maximum value of the total error is always smaller than twice the sum of its components.

Under production conditions the shape of the cross section is usually determined by measuring the "radial wobble"; for this purpose the difference between the largest and smallest reading of the measuring instrument is taken. Such a checking method does not provide either the characteristic variations of the total error curve or even the possibility of separating eccentricity from the errors of shape. A complete recording of the wobble curve for set angles of rotations and its subsequent deciphering by means of simple calculations provides the possibility of establishing the value and direction of the separate components of the total error, which is very important for the analysis of the accuracy of machining. Thus, for instance, eccentricity is the result of a fixing error, and distortion of shape is due to insufficient rigidity of the elastic system consisting of the machine, the component, and the tool. With the knowledge of the relative importance of each component it is possible to find the means of improving accuracy in machining.

LITERATURE CITED

[1] G. Berndt, Zeitschrift für Instrumentenkunde No. 63 (1943).

[2] Yu. N. Lyandon, Foundations of Interchangeability in Engineering [In Russian] (Mashgiz, 1958).

MECHANICAL MEASUREMENTS

CHECKING UNIDIRECTIONAL HYDRAULIC PULSATING TEST MACHINES

F. S. Savitskii

It is recommended to check hydraulic pulsating test machines by measuring the strain in samples of varying stiffness at different tensions with strain gauges and subsequently calibrating them statically [1]. The application of such a calibration method in compulsory State testing is made difficult by the comparatively complex apparatus required for these tests and the error of measurements which amounts to 3 to 5%, whereas according to the technical requirements the error of the strain gauge, which measures the pulsating load, must not exceed 3%.

The NIKIMP has developed an opticomechanical dynamometer for 50, 25, and 10 ton-wt. [2]. The dynamometer measures a pulsating dynamic load from 0.3 of its maximum load with an error not exceeding ±1.5%* for single measurements and ± 1% for a mean of three measurements.

On the basis of our investigation of various methods of checking hydraulic pulsating test machines, we have recommended another method of determining the pulsating load. This method is based on the functional relation between the force of compression and the diameter of the imprint due to an elastic impressing of a sphere into the surface of an elasto-plastic body:

$$P = kd^3, \tag{1}$$

where P is the force of compression;
d is the diameter of the elastic imprint; and
k is the conversion factor, which depends on the radius of the sphere and the elastic constants of the bodies being compressed.

$$k = \frac{E}{12(1-\mu)^2 R}. \tag{2}$$

Here** E is the modulus of elasticity;
μ is the Poisson's constant;
R is the radius of curvature of the spherical segment.

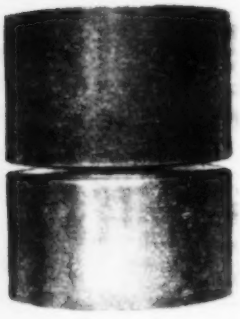
In practice, it is easier to determine coefficient k from the static calibration of compressing bodies.

This formula holds both for static and shock compression of bodies, if their relative velocity does not exceed 7-8 m/sec. At higher velocities residual deformations may arise, and in addition the transverse and longitudinal vibrations which arise at the impact affect the distribution of local tensions and deformations. The use of this formula for determining the force of a shock impression of a ball into the sample proved very fruitful [3, 4].

* The error of 1.5% corresponds to twice the value of the root-mean-square error.

** It is assumed in Eq. (2) that the compressing bodies have the same elastic constants. For different elastic constants $k = \frac{1}{24}\left(\frac{E_1}{1-\mu_1^2} + \frac{E_2}{1-\mu_2^2}\right)$.

For checking the manometer used in the pulsating hydraulic test machine we designed and constructed a dynamometer which consisted of two cylinders made of 5KhVG brand steel 75 mm in diameter and height. One of the cylinders has both its ends flat, the other has one end flat and the other spherical with an R = 250 mm (see figure).



For checking the manometer of the hydraulic pulsating machine, the dynamometer is placed between the grips of the machine in such a manner that the operation axis of the force coincides with that of the dynamometer, and then a definite pulsating load is applied which compresses the dynamometer. After the loading of the machine and the dynamometer there remains, on the flat surface of one of the cylinders, an imprint due to the elastic compression of the sphere into the flat surface of the other cylinder. The imprint becomes especially clear if the flat surface of the cylinder, which faces the spherical surface of the other cylinder, is covered before testing with a thin layer of an emulsion prepared from a mixture of soot and carbon tetrachloride.

The imprints obtained in the compression of the dynamometer with a pulsating dynamic load of 10, 20, and 30 ton -wt. had the following dimensions: 11.12, 13.92, and 16.01 mm.

Owing to the good contrast of the imprint boundaries their diameters could be measured by means of a measuring microscope with an error not exceeding 0.01 mm. After measurement, the imprints were rubbed off with cotton and the sample was then ready for further tests.

This dynamometer was repeatedly loaded by means of a grade II 50 ton -wt. dynamometer with a static load of 10 ton -wt. From the test results the root-mean-square error was calculated to be 0.79%.

Editorial Note. The errors of the above dynamometer and the one of the NIKIMP [2] are about the same. The disadvantage of the former consists in the necessity of lifting the instrument after each test for measuring the imprint. Its use for arbitrary testing is completely justified since it improves the reliability of results obtained by two equally accurate methods based on different principles.

The further development of the proposed original method should be conducted with the view of eliminating the observed defect and extending this method to hydraulic two-directional pulsating machines.

LITERATURE CITED

[1] S. V. Serensen, M. E. Graf, and L. A. Kozlov, Fatigue Testing Machines [In Russian] (Mashgiz, Moscow, 1957).

[2] I. M. Roitman, Izmeritel'naya Tekhnika No. 2 (1956).

[3] S. B. Ainbinder, Izvestiya Akad. Nauk Latv. SSR (1952).

[4] B. A. Vandyshev and F. S. Savitskii, Physics of Metals and Metallurgy [In Russian] (1958) Vol.6, 3rd ed.

ERRORS IN CHECKING DYNAMOMETERS WITH A CONSTANT LOAD

O. N. Fofanov

In the method previously described by us [1] the forces required for calibration or checking of dynamometers were obtained by multiplying the force exerted by a given load by means of the actual dynamometers being tested. For this purpose, two dynamometers were connected in series as shown in Fig. 1. At point p a load exerting force P was periodically applied and at point q the system was loaded with force Q by means of a traction device. It is assumed that the dynamometers are loaded with forces P, 2P, 3P, . . . , nP. If they are loaded by means of weights directly exerting forces P, 2P, 3P, . . ., nP, each loading step will differ from the adjacent one by exactly the value of P. The curve showing the relation between the forces and the corresponding displacement of the measuring mechanism pointer will in this case have the shape shown in Fig. 2.

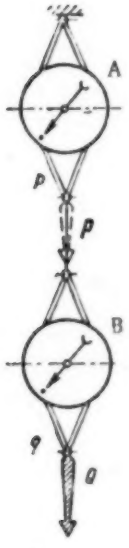


Fig. 1

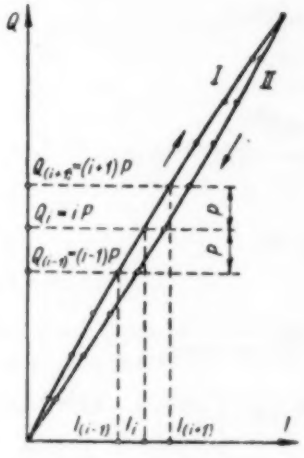


Fig. 2. Q is the operating force; I are the readings of the indicator; I) relationship for loading; II) relationship for unloading.

The method under consideration differs from the above in having the forces exerted on the dynamometers interchanged as shown in Fig. 3 when passing from one loading step to another. (Here I denotes loading and II unloading; the transition process is expressed in a graph of force versus displacement of the dynamometer pointer.)

Assuming that in a general case the dynamometers are loaded initially by a certain force Q_i, let us examine the building up of forces in loading:

$$I^{(Ai)} = K^{(Ai)}Q_i,$$
$$I^{(Bi)} = K^{(Bi)}Q_i,$$

where $I^{(Ai)}$, $I^{(Bi)}$ are the dynamometer readings corresponding to the displacement of the pointer under the action of force Q_i; and $K^{(Ai)}$, $K^{(Bi)}$ are the coefficients which relate the readings with the actuating forces.

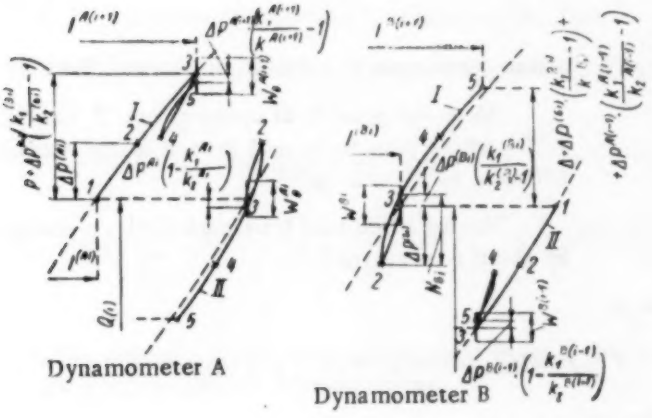


Fig. 3

By applying force P at point p (Fig. 1) we shall obtain point 2 (Fig. 3), which corresponds to the changed forces, and the equations

$$I^{(Ai)}+\Delta I^{(Ai)} = I^{(Ai)}+k_1^{(Ai)}\Delta P^{(Ai)},$$

$$I^{(Bi)}-\Delta I^{(Bi)} = I^{(Bi)}-k_1^{(Bi)}\Delta P^{(Bi)}.$$

Here $\Delta I^{(Ai)}$, $\Delta I^{(Bi)}$ are the variations in readings due to changed forces;

$\Delta P^{(Ai)}$, $\Delta P^{(Bi)}$ are the variations in forces; and

$k_1^{(Ai)}$, $k_1^{(Bi)}$ are coefficients relating the variations of readings to the forces which produce these variations.

By increasing the force applied to point q (Fig. 1) we restore the value of $I^{(Bi)}$.

The value of the additional force required is expressed by the relation:

$$\Delta I^{(Bi)} = k_1^{(Bi)}\Delta P^{(Bi)} = k_2^{(Bi)} N_{Bi},$$

where N_{Bi} is the additional force; and

$k_2^{(Bi)}$ is the coefficient relating the additional force to $\Delta I^{(Bi)}$.

Whence

$$N_{Bi} = \frac{k_1^{(Bi)}}{k_2^{(Bi)}}\Delta P^{(Bi)}.$$

For the restored $I^{(Bi)}$ we have:

$$I^{(Bi)} = (K+\xi_K)^{(Bi)}\left[Q_i-\Delta P^{(Bi)}+N_{Bi}\right] =$$

$$= (K+\xi_K)^{(Bi)}\left[Q_i+\Delta P^{(Bi)}\left(\frac{k_1^{(Bi)}}{k_2^{(Bi)}}-1\right)\right],$$

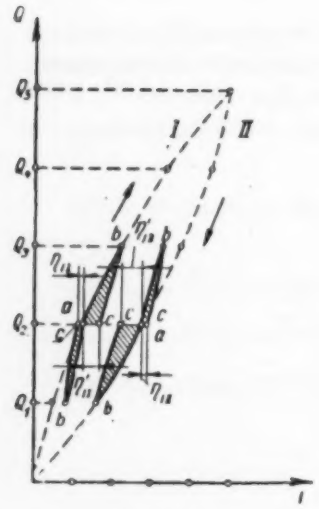


Fig. 4

where ξ_K is the variation of coefficient K due to the difference between coefficients k_1 and k_2, and dynamometer A will then read:

$$I^{A(i+1)} = K^{A(i+1)}\left[Q_i + P + \Delta P^{(Bi)}\left(\frac{k_1^{(Bi)}}{k_2^{(Bi)}}-1\right)\right],$$

which corresponds to points 3 on curves I (Fig. 3).

Moreover point 3 of dynamometer B can fall within a certain area $W^{(Bi)}$ whose dimensions will depend on the maximum possible difference between $k_1^{(Bi)}$ and $k_2^{(Bi)}$.

Having lifted load P we shall obtain a change in forces represented by points 4 on curves I.

Having for dynamometer A:

$$I^{A(i+1)}-\Delta I^{A(i+1)} = I^{A(i+1)} - k^{A(i+1)}\Delta P^{A(i+1)},$$

let us restore the value of $I^{A(i+1)}$ by adding force $N_{A(i+1)}$ which is related by expression:

$$\Delta I^{A(i+1)} = k_1^{A(i+1)}\Delta P^{A(i+1)} = k_2^{A(i+1)} N_{A(i+1)}.$$

Hence

$$N_{A(l+1)}=\frac{k_1^{A(l+1)}}{k_2^{A(l+1)}}\Delta P^{A(l+1)}$$

and

$$I^{A(l+1)}=(K+\xi_K)^{B(l+1)}\left[Q_l+P+\Delta P^{(Bl)}\left(\frac{k_1^{(Bl)}}{k_2^{(Bl)}}-1\right)+\right.$$

$$\left.+\Delta P^{A(l+1)}\left(\frac{k_1^{A(l+1)}}{k_2^{A(l+1)}}-1\right)\right],$$

$$I^{B(l+1)}=K^{B(l+1)}\left[Q_l+P+\Delta P^{(Bl)}\left(\frac{k_1^{(Bl)}}{k_2^{(Bl)}}-1\right)+\right.$$

$$\left.+\Delta P^{A(l+1)}\left(\frac{k_1^{A(l+1)}}{k_2^{A(l+1)}}-1\right)\right],$$

which correspond to points 5 on curves I.

By further developing these formulas in the same manner, it will be seen that for any n-th step of loading, the relation between the actuating forces and the dynamometer pointer displacements will be expressed by relations:

$$I^{A(l+n)}=K^{A(l+n)}\left[Q_l+nP+\sum_{t=1}^{t=n-1}\Delta P^{A(l+t)}\left(\frac{k_1^{A(l+t)}}{k_2^{A(l+t)}}-1\right)+\sum_{t=1}^{t=n-1}\Delta P^{B(l+t)}\left(\frac{k_1^{B(l+t)}}{k_2^{B(l+t)}}-1\right)\right]. \quad (1)$$

$$I^{B(l+n)}=K^{B(l+n)}\left[Q_l+nP+\sum_{t=1}^{t=n}\Delta P^{A(l+t)}\left(\frac{k_1^{A(l+t)}}{k_2^{A(l+t)}}-1\right)+\sum_{t=1}^{t=n-1}\Delta P^{B(l+t)}\left(\frac{k_1^{B(l+t)}}{k_2^{B(l+t)}}-1\right)\right]. \quad (2)$$

In unloading (curves II in Figs. 3 and 4), the changes of the forces acting on the dynamometers A and B are represented by points 1, 2, 3, 4, and 5 which correspond to various stages in the transition from one step to another. The transition process is similar to the one analyzed in loading. The only difference consists in the restoration of readings I^A and I^B by decreasing, instead of increasing, the force at point q (Fig. 1).

The relations between the dynamometer readings and the forces have the form:

$$I_0^{A(l-n)}=K^{A(l-n)}\left[Q_l-nP+\sum_{t=1}^{t=n-1}\Delta P^{A(l-t)}\left(1-\frac{k_1^{A(l-t)}}{k_2^{A(l-t)}}\right)+\sum_{t=1}^{t=n}\Delta P^{B(l-t)}\left(1-\frac{k_1^{B(l-t)}}{k_2^{B(l-t)}}\right)\right]. \quad (3)$$

$$I^{B(l-n)}=K^{B(l-n)}\left[Q_l-nP+\sum_{t=1}^{t=n-1}\Delta P^{A(l-1)}\left(1-\frac{k_1^{A(l-t)}}{k_2^{A(l-t)}}\right)+\sum_{t=1}^{t=n-1}\Delta P^{B(l-t)}\left(1-\frac{k_1^{B(l-t)}}{k_2^{B(l-t)}}\right)\right]. \quad (4)$$

It follows from (1), (2), (3), and (4) that the errors which occur in producing the required forces and arise in the transition from one loading step to another have the form:

$$\xi_P=\pm\left[\Delta P^A\left(\frac{k_1^A}{k_2^A}-1\right)+\Delta P^B\left(\frac{k_1^B}{k_2^B}-1\right)\right]. \quad (5a)$$

They consist of the systematic component Θ_p and the random one δ_p.

$$\xi_p = \Theta_p + \delta_p. \tag{5b}$$

Normally, in calibration or checking several repeated measurements are made by means of which further relations are obtained:

$$\begin{aligned} I_{am\cdot 1} &= K_{am\cdot 1} Q_1, \\ I_{am\cdot 2} &= K_{am\cdot 2} Q_2, \\ &\cdots\cdots\cdots\cdots \\ I_{am\cdot n} &= K_{am\cdot n} Q_n, \end{aligned} \tag{6}$$

where I_{am} is the arithmetic mean of readings for each loading step;

Q is the actual force;

K_{am} is the mean value of the coefficients relating the forces to the readings.

The number of loading steps n is usually taken as 10 [2].

The dynamometer should pass the test if at each loading step the sum of the error established by the application of the actual force Q and the error of the force Q itself does not exceed the tolerances provided for the dynamometer.

In the method under consideration, we shall have for any n-th step of measurement:

$$\begin{aligned} I_{am^n} &= (K_{am^n} \pm \sigma_{kn}) \left(nP + \sum_{i=1}^{i=n} \Theta_{Pi} \pm \sigma_{Qn} \right) \simeq \\ &\simeq K_{am^n} nP + K_{am^n} \sum_{i=1}^{i=n} Q_{Pi} \pm K_{am^n} \sigma_{Qn} \pm \sigma_{Kn} nP. \end{aligned} \tag{7}$$

where σ_{K_n} is the root-mean-square deviation of coefficient K at the n-th loading step;

σ_{Q_n} is the root-mean-square deviation of the force produced at the n-th loading step. It characterizes the error due to random components, which are represented in expression (5b) as δ_p; and

Θ_{P_i} is the same as in expression (5b).

The structure of σ_{Q_n} and Θ_{P_i} is determined from expression

$$\begin{aligned} \sigma_{Qn} &= \sqrt{\sum_{i=1}^{i=n} \sigma_{Pi}^2} = \sqrt{\sum_{i=1}^{i=n} (\sigma_{Pi}^{A\,2} + \sigma_{Pi}^{B\,2})} = \\ &= \sqrt{\sum_{i=1}^{i=n} \sum_{k=1}^{k=m} \left[(\eta_{Pi}^A - \delta_{Pk}^A)^2 + (\eta_{Pi}^B - \delta_{Pk}^B)^2 \right] \frac{1}{m-1}}; \end{aligned} \tag{8}$$

$$\Theta_{Pi} = \eta_{Pi}^A + \eta_{Pi}^B,$$

where m is the number of repeated loadings;

$$\eta^{A}_{|Pl} = \frac{1}{m}\sum_{l=1}^{l=m} \Delta P_l^A \left(\frac{k_1^A}{k_2^A} - 1\right)_l ,$$

$$\eta^{B}_{|Pl} = \frac{1}{m}\sum_{l=1}^{l=m} \Delta P_l^B \left(\frac{k_1^B}{k_2^B} - 1\right)_l$$

The results obtained by means of this method were repeatedly compared with those obtained with the reference test equipment certified by the Committee of Standards, Measures, and Measuring Instruments, and their agreement was found to be satisfactory (the difference was within the tolerances specified for the dynamometers).

TABLE 1

Q, kg-wt	Loading				Unloading			
	I	σ_I	I'	σ'_I	I_0	σ_{I0}	I'_0	σ'_{I0}
0	0		0		0		0	
500	52.1	0.37			53.4	0.62		
1000	105.1	0.72	105.0	0,31	107.4	1.19	108.6	0.17
1500	156.9	0.68			158.8	1.82		
2000	209.5	0.54	208.6	0.28	212.0	1.80	212.1	0.26
2500	259.0	0.57			261.0	2.04		
3000	308.0	0.52	307.0	0,32	310.0	1.55	310.6	0.25
3500	357.8	0.50			359.0	1.25		
4000	406.7	0.59	406.8	0,26	407.5	1.02	408.0	0.42
4500	452.5	0.56			453.0	0.68		
5000	504.9	0.68	504.8	0.30				

Note. Q is the actual value of the force, kg-wt; I and I_0 are readings according to the method under consideration for loading and unloading, equal to the displacement of the pointer from zero, mm; I' and I'_0 are readings for loading and unloading obtained by means of the direct loading equipment, mm; σ_I and σ_{I0} are the root-mean-square deviations of reading for repeated measurements according to the method under consideration; σ'_I and σ'_{I0} are the same quantities obtained with the direct loading equipment.

TABLE 2

Q, kg-wt	Loading				Unloading			
	η_{II}	η'_{II}	σ_{II}	σ'_{II}	η_{III}	η'_{III}	σ_{III}	σ'_{III}
1000	−0,07	+2,10	0,14	0,37	−0,02	−3,17	0,14	0,41
2000	+0,07	+1,56	0,22	0,33	+0,08	−1,56	0,26	0,40
3000	+0,11	+1,95	0,15	0,40	+0,24	−1,66	0,26	0,37
4000	+0,36	+1,95	0,16	0,36	+0,19	−1,98	0,40	0,27
5000	−0,01		0,17					

Experimental data provides an idea of the magnitude of Θ_p and δ_p for traction dynamometers. Dynamometers of 5000 kg-wt. of the Scheffer and Budenberg type with a tolerance of ± 1% were used in the experiments. For an accurate determination of the dynamometer pointer displacements, the dynamometers were supplied with standard markers which provided means of registering readings.

Table 1 shows comparative data in determining the characteristic of a dynamometer by the above method and by means of certified equipment based on direct loading.

Direct loading was carried out in steps of 1000 kg-wt. which were determined by the operational facilities of the equipment.

In both cases, measurements were repeated 11 times.

The variation of coefficients k_1 and k_2 during the changing and subsequent restoration of the forces acting on the dynamometers were measured for the same dynamometer. This operation was carried out as shown in Fig. 4. The dynamometer was subjected to direct loading with weight of the value of Q. The loading steps were equal to 1000 kg-wt. The variations of the forces along the abc line were made at each change of the loading step, i.e., first Q was produced, then it was changed from point a to point b and restored to its former value corresponding to point c. The variation of the force was achieved by the addition and lifting (or vice versa) of a weight of 1 ton.

Each abc measurement was repeated 11 times and the values of η_I and σ_I, the systematic and root-mean-square deviations corresponding to points a and c were determined. The figures thus obtained are given in Table 2 which shows that the values of η_{II} and η_{III} are considerably (about one order) lower than η'_{II} and η'_{III}. These variations are the sources of the possible errors in providing the required forces according to the method under consideration. Similarly σ_{II} and σ_{III} determine the random errors in producing the required forces.

If the required forces are produced by means of two dynamometers A and B (Fig. 1), the above systematic errors produced when changing from one step to another will have the value of the order of:

$$\frac{\eta_{lp}^{A} + \eta_{p}^{B}}{P_{max}} = \frac{\theta}{P_{max}} = \frac{2\eta_{l1}}{I_{max}}.$$

The corresponding referred root-mean-square errors will be of the order of

$$\frac{\sqrt{\sigma_{p}^{A\,2} + \sigma_{p}^{B\,2}}}{P_{max}} = \frac{\sqrt{2}\,\sigma_{I}}{I_{max}}.$$

where P_{max} is the maximum force measurable by the dynamometer; and

I_{max} is the reading corresponding to the maximum force.

TABLE 3

For θ, %	Loading					unloading			
	−0.03	+0.03	+0.04	+0.14	<0.01	<0.01	+0.03	+0.1	+0.04
For σ, %	0.04	0.06	0.04	0.05	0.05	0.04	0.07	0.07	0.11

Thus, for a traction dynamometer which has a tolerance of ± 1% the above values of the systematic and random errors due to changing from one step to another are characteristic (Table 3).

LITERATURE CITED

[1] O. N. Fofanov, Izmeritel'naya Tekhnika No. 4 (1958).*

[2] The Control of Machines and Instruments for Mechanical Tests of Metals [In Russian] (Metallurgizdat, 1949).

* See English translation.

ESTABLISHMENT OF A PRACTICAL TEMPERATURE SCALE IN THE RANGE OF 10-90° K

A. S. Borovik-Romanov, M. P. Orlov, and P. G. Strelkov

Calibration results of an All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements group standard

Below, we give the results of the comparison of four platinum resistance thermometers with one gas thermometer.

The apparatus used in the tests, consisting of a gas thermometer, platinum thermometers, and a cryostat, was described in [1, 2, 3].

Calculation of the Gas Thermometer Temperatures from the Measured Pressures

Derivation of the formula. For thermometrical purposes, it is best to use the empirical formula [4]:

$$PV = A + BP + CP^2 + \ldots, \tag{1}$$

where A, B, and C are the virial coefficients which depend only on temperature.

If the specific volume is measured in Amagat units and the pressure in normal atmospheres, then $A = A_0 \frac{T}{T_0}$, where for helium $A_0 = 0.99949 \pm 0.00001$. In the temperature range of 90° to 10° K, the value of C varies between $1 \cdot 10^{-6}$ and $1.3 \cdot 10^{-5}$. Hence, for $P_0 \leq 3$ atm the neglecting of the squared term will lead to an error not exceeding 0.0003° K and it is possible to use the equation

$$PV = A\left(1 + \frac{B}{A}P\right) = A_0 \frac{T}{T_0}\left(1 + \frac{B}{A_0} \cdot \frac{T_0}{T} P\right). \tag{2}$$

The second term of (2) is of the order of 10^{-3}, hence the assumption that $A_0 = 1$ and $P = \frac{T}{T_0} P_0$ will produce an error not exceeding 0.0001°. Then the equation will take the form:

$$PV = A_0 \frac{T}{T_0}(1 + BP_0). \tag{3}$$

Writing (3) for temperature T to be measured and for temperature T_r, used as the reference point for determining the constant of the gas thermometer, and dividing the first equation by the second, we obtain:

$$\frac{P_\tau V_\tau}{P_r V_r} = \frac{T}{T_r} \cdot \frac{1 + B_\tau P_0}{1 + B_r P_0}. \tag{4}$$

By solving (4) with respect to T and neglecting second order terms, thus making an error of measurement not exceeding 0.0003°, we obtain:

$$T = T_r \frac{P_\tau}{P_r} \cdot \frac{V_\tau}{V_r} [1 + (B_r - B_\tau) P_0]. \quad (5)$$

An essential advantage of the above-mentioned gas thermometer without a dead space consists in the specific volume of gas in the thermometer container at all the measured temperatures being equal to

$$V = Kv, \quad (6)$$

where v is the volume of the gas container.

The variation of the container volume with temperature can be represented by:

$$v_\tau = v_r [1 + \Delta_\alpha (T)]. \quad (7)$$

The maximum value of the correction Δ_α in the region of 10-90° K does not exceed 0.04° in terms of equivalent temperature. By substituting (6) and (7) in (5), and neglecting second-order terms, we obtain the final formula for calculating the temperature determined by the gas thermometer:

$$T = T_r \frac{P_\tau}{P_r} + T (B_r - B_\tau) P_0 + T \Delta_\alpha (T) =$$

$$= C P_\tau + \Delta T_r + \Delta T_\alpha. \quad (8)$$

All the approximations which were made can lead to an inaccuracy not exceeding 0.001°.

The proposed formula appears to us more convenient than the one adopted in the literature on the subject of gas thermometry [4, 5] and based on a centigrade scale with the zero at the temperature of melting ice: firstly because in the region of low temperatures, it is more expedient to use an absolute scale and this procedure is generally accepted; secondly because the proposed formula does not limit the choice of the reference measuring point, which is especially important for low temperature measurements.

Choice of the reference point. The temperature of normal boiling of oxygen was taken as the reference point for measurements in the region of 10-90° K. This procedure provides a threefold gain in sensitivity as compared with measurements based on the melting temperature of ice, and the results thus obtained are related to the International Temperature Scale.

According to the OST VKS 6954 the boiling temperature of oxygen is equal to − 182.97° C. With T_0 = = 273.16° K the absolute temperature of boiling oxygen is T_{O_2} = 90.19° K. If the specified boiling temperature of oxygen is changed the scale can be easily altered.

Correction for an imperfect scale. In order to determine correction ΔT_g for the imperfect scale from formula

$$\Delta T_g = T (B_{O_2} - B_\tau) P_0$$

the value of the second virial coefficient must be known. We did not determine it ourselves but used the semi-empirical formula proposed by Keyes [6]: $10^3 B = T^{-1/4} (2.94047 - 13.212\, T^{-1/2} - 4.39\, T^{-1})$ and B_{O_2} = = $+ 0.487 \cdot 10^{-3}$.

In order to evaluate the error connected with the use of a correction for an imperfect scale, we calculated the value ΔT_g directly from known experimental values of B_T [7-16] and from the assumed value of B_{O_2} = = $0.487 \cdot 10^{-3}$ and compared it at corresponding temperatures with the value of ΔT_g adopted in this work (Fig. 1). The discrepancies in the values of T_g calculated on the basis of sufficiently reliable data obtained since 1925 did not exceed ± 0.005°.

Correction for the temperature expansion of the container. It will be seen from (8) that in order to determine ΔT_α it is necessary to know the characteristic of the bulk temperature coefficient $\alpha(T)$ of the material from which the container is made

$$\Delta T_\alpha = T\left(\frac{v_T}{v_{O_2}} - 1\right) = 3T\int_{90.19}^{T} \alpha(T)dT. \tag{9}$$

Brickwedde and Hoge [17] derived on the basis of the linear temperature coefficient of copper the following formula:

$$v_T = v_0\,[0.991171 + 3.267\cdot 10^{-6}\,T + 1.064\cdot 10^{-7}\,T^2], \tag{10}$$

which we used for calculating the correction

$$\Delta T_\alpha = T\left[-1169.4 + 32.97\frac{T}{10} + 10.72\left(\frac{T}{10}\right)^2\right]\cdot 10^{-6}. \tag{11}$$

The corresponding correction curve for the thermal expansion ΔT_α is shown in Fig. 2 (solid line).

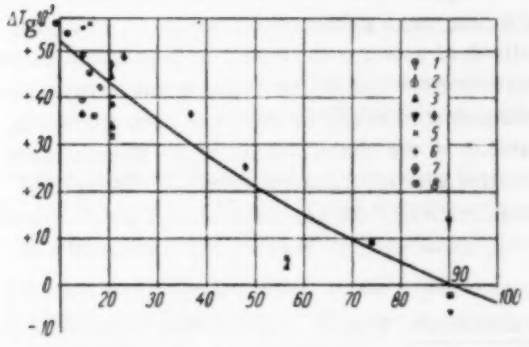


Fig. 1. Curve of the scale imperfection correction ΔT_g, calculated from known experimental values of B_{O_2}. 1) Leiden, 1907 [7]; 2) Leiden, 1908 [7]; 3) Leiden, 1923 [8, 11]; 4) PTR, 1924 [10]; 5) Leiden, 1924 [9]; 6) Leiden, 1925 [12]; 7) PTR, 1926 [13]; 8) Leiden, 1927 [14, 15]; 9) Leiden, 1947 [16].

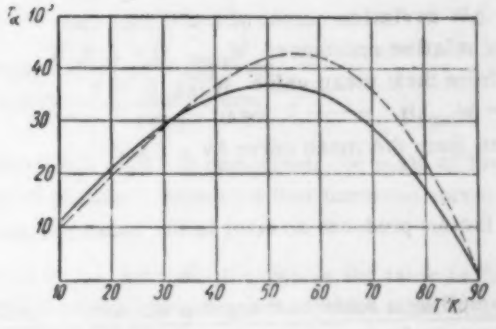


Fig. 2. Correction curve for the thermal expansion ΔT of the gas thermometer container.

When the present work was completed and the table of W(T) calculated, there appeared a report on new, more detailed measurements of the linear temperature coefficient of copper [19].* We found an analytical relationship which described sufficiently well these measurements and from (9) determined the values of ΔT_α, which are shown in Fig. 2 by a dotted line.** It will be seen from Fig. 2 that the maximum deviation of ΔT_α occurs at 60° K and amounts to 0.008°. We did not consider it advisable to carry out a cumbersome calculation in compiling a new T(W) table in order to introduce this correction, which hardly exceeds the statistical errors of gas thermometer measurements.

Measurement Results

Three cycles of measurement were made with two independent fillings of the gas thermometer. For each filling the constant of the gas thermometer was determined, consisting of the coefficient of the first term of the formula (5) $C = \left[\frac{T}{P}\right]_{O_2}$ at a temperature close to the boiling point of oxygen.

* These calculations were made by D. I. Sharevskaya.

** The linear temperature coefficient was measured by S. I. Novikova, and her values coincided with those of Rubin [19].

The temperature was measured by means of platinum resistance thermometers calibrated at the boiling temperature of oxygen [20].

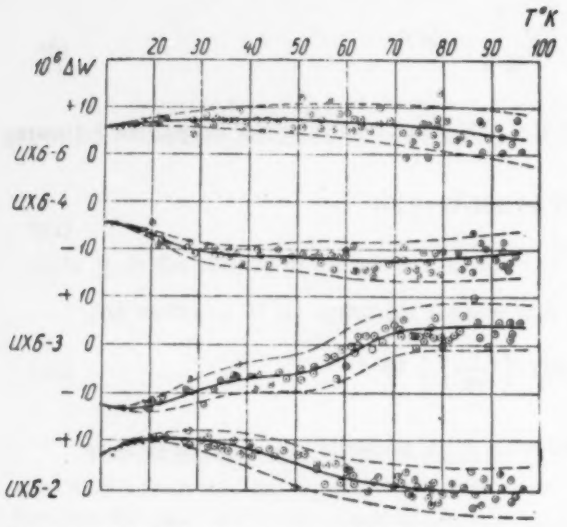


Fig. 3. ΔW deviation curves of individual thermometer relative resistances W_{ux6i} (i = 2, 3, 5, and 6) from their mean value W_{ux6} ($\Delta W = W_{ux6i} - W_{ux6}$); ——) mean curve; – – – –) deviations from the mean curve by ± 0.001°.

The error of the mean value of the constant amounted to ± 0.003%, i.e., expressed in the temperature equivalent at 90° K it was $\pm 3 \cdot 10^{-3}$° K. It should be noted that we did not observe any systematic variations of the constant during six months. This bears witness to the complete stability both of the gas thermometer and the thermometers of the group standard.

The values of the relative resistances W_T of all the thermometers were determined 107 times at various temperatures between 10.7 and 95° K. The values of W_T for all the four thermometers were found to be very close to each other. We therefore characterized the whole group of thermometers by a mean value of W_T. Thus, the errors connected with the measurement of the resistance of each thermometer were decreased.

Figure 3 shows the deviations of each thermometer from the mean values of the group. The deviation of individual points with respect to the smooth curves represents the sum of statistical errors of resistance measurements made by means of potentiometers, the stability of the characteristic of the thermometer sensitive elements, and the effect of the possible irregularities in the gas thermometer unit. The effect of these factors produces an error in the measured values of W_T amounting to several ten thousandths of a degree.

Compiling a table of the group standard smoothed-out calibration. Former studies of the relation between the platinum resistance and temperature showed the impossibility of representing this relation by a sufficiently simple analytical function. We compiled, therefore, similarly to Brickwedde and Hoge [17], a table of smoothed-out values of W(T), which represented as closely as possible the experimental results obtained. The procedure in compiling this table consisted in the following.

Landau and Pomeranchuk [21] proposed for the range of low temperatures the following theoretical formula for the relation between temperature and the resistance of metals of the platinum group

$$R_T = A + BT^2 + CT^5. \tag{12}$$

Our data in the range of 10-15° K agreed well with this formula and we used it for interpolation purposes. By the method of least squares we determined the coefficients in (12) from 15 experimental values obtained in the range of 10.7 to 14.6° K:

$$10^6 W_{ux6} = 439.31 + 2.3970\, T^2 + 0.00099060\, T^5. \tag{13}$$

Of the 15 experimental values obtained only three had deviations exceeding ± 0.005°. Above 15° the experimentally obtained values do not fit into (13) and we plotted a correction curve for the range between 13.5 and 17° K, where these deviations did not exceed $5 \cdot 10^{-3}$. By means of the formula and the correction curve a table of $W_{ux6}(T)$ values was compiled for the range of 10 to 17° K.

For compiling tables in the range of higher temperatures (17-95° K), it was found possible to use the same method of finding power series covering small temperature ranges and plotting correction curves to these series. In trying to reduce the amount of calculating work, however, we used instead of the power series the approximate table of W(T) relations of Brickwedde and Hoge [17], by means of which with Matthieson's rule (see, for instance,

[22]), we calculated a new table for our platinum which served as the first approximation for W (T). By means of differences between the experimental values of W_{ux6} and those in the table of the first approximation, a table of the second approximation was compiled. It was found to be insufficiently smooth due to the initial values in the table of Brickwedde and Hoge having been rounded off to $1 \cdot 10^{-6}$, whereas we considered it necessary to have a table providing an accuracy of $1 \cdot 10^{-7}$ for W(T) calculations. The table was readjusted by means of a graphical alignment of second differences. The tables from 10 to 17° K and 17 to 95° K were joined to each other by consecutive alignment of the place of their junction.

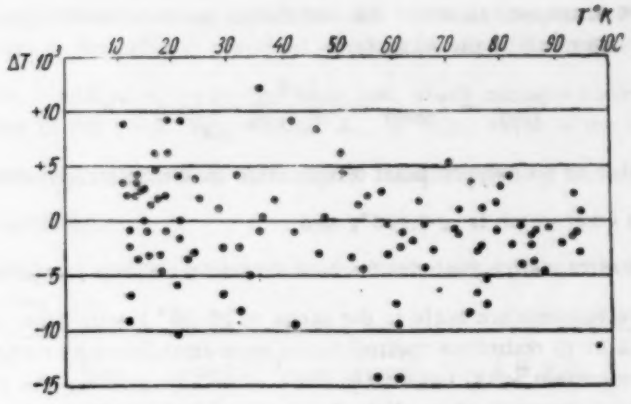


Fig. 4. Deviations of the experimental values of W_{ux6} from those in the table of smoothed-out temperature equivalents.

Such a table published in [23] comprises the basic results of this work. It determines the scale of the group standard for the range of 10-90° K, and together with the group of platinum resistance thermometers serves as the means for producing a practical temperature scale in this range.

Figure 4 shows the deviation of the experimental values of W_{ux6} from those given in the table in the form of their temperature equivalents. The root-mean-square deviation of the points from the Y-axis amounts to $\pm 4.9 \cdot 10^{-3}$ degrees.

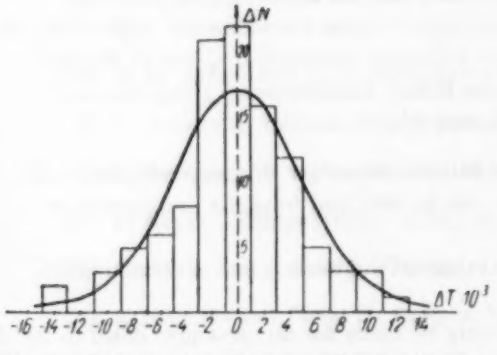


Fig. 5. Distribution diagram of experimental result deviations ΔN from the smoothed-out tabulated values, W_{ux6}.

Figure 5 shows the distribution diagram of ΔN deviations of the experimental from the tabulated values in a given range with respect to the value of their deviations. This diagram is in good agreement with the Gauss distribution curve shown in the same diagram and calculated for a root-mean-square deviation of $\sigma = \pm 0.0049$. All this confirms the absence of any systematic deviations between the smoothed-out table and experimental data.

Since in thermometric testing it is usually necessary to find T from the measured values of W_T, this table [23] was redrawn by the reversed interpolation method* [24].

Errors in calibrating a group standard. We analyzed carefully all the errors which could occur in a calibration table of a group standard.

The main source of random experimental errors consisted of errors in measuring pressure (approximately ± 0.005°). Since the table is based on 107 measurements the effect of these errors is decreased to a value of approximately ± 0.002°. Another important error is that of

* The table was computed by Professor N. N. Meiman's mathematical group and executed by N. T. Krutikova.

determining the gas thermometer constant, which in conjunction with the error of calibration at the oxygen point leads to an error proportional to temperature amounting to approximately $(1\text{-}5)\cdot 10^{-3}$ degrees. Thus the total error due to measurements lies in the limits of $(2\text{-}5)\cdot 10^{-3}$ degrees. To these errors should be added the systematic errors due to the correction for an imperfect scale and for thermal expansion. The correction for an imperfect scale was introduced from published data and its estimation is difficult. According to the reasoning given above, we consider that the former does not exceed ± 0.005° and the latter requires an additional correction of approximately 0.007°. When more reliable data on the virial coefficients is obtained the latter errors can be reduced by simple recalculation.

Adding up all the above errors we can assert that the difference between the group standard and the thermodynamic scale can be expressed by the formula:

$$T_{\text{ther}} - T_{\text{pract}} = T\left(\frac{T_{O_2}}{90.19} - 1\right) \pm \eta + \delta,$$

where T_{O_2} is the precise value of the oxygen point temperature on the thermodynamic scale;

η is the total scale error which is $\leq 0.006°$; and

δ is the systematic error, which includes the new data on the linear temperature coefficient of copper.

Comparison of the above temperature scale in the range of 10-90° K with other low-temperature scales. Low-temperature scales for platinum resistance thermometers were established by comparing them with a gas scale not only in the USSR (the present work) but also in three other laboratories: the USA National Bureau of Standards (1933 and 1939); the German Physicotechnical Institute PTR (1927, 1932, and 1936) and in the Leiden Laboratory (1936). All the thermometers used in these tests were made of substantially less pure platinum than the one used for the group standard thermometers. The calibration table differences, which depend on the purity of platinum, masked the actual discrepancies between the scales obtained in various laboratories.

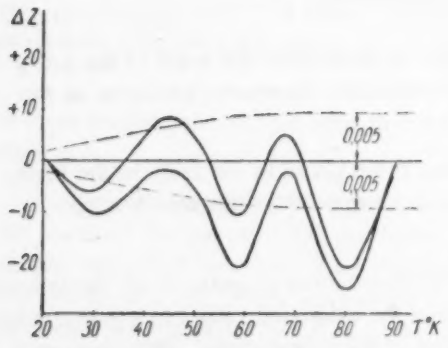


Fig. 6. Comparison of the existing temperature scales based on gas thermometer measurements. Top curve $\Delta Z = Z_{NBS} - Z_{VNIIFTRI}$ [24]; bottom curve $\Delta Z = Z_{L \text{ and } M} - Z_{VNIIFTRI}$ [27].

In recent years calibrations of thermometers made of purer platinum ($\alpha \geq 0.003925$) became available, but instead of being compared with a gas thermometer they were compared with a platinum thermometer which was calibrated in 1939 against a gas thermometer (see for instance, [25] and [26]). The purity of the platinum of these thermometers approaches that of the All-Union Scientific Research Institute of Physico-Technical and Radiotechnical Measurements group standard thermometers ($\alpha = 0.003925$).

An idea of the relation between our group standard scale and that of the NBS can be obtained from the comparison of Z-functions ($Z = \frac{R_T - R_{H_2}}{R_{O_2} - R_{H_2}}$) calculated from the calibration tables of the corresponding thermometers made of pure platinum in other laboratories. (This comparison could only be made for temperatures down to 20° K, since for lower temperatures no published data exists.)* Figure 6 shows a comparison of the calibrations of the group standard thermometers and those made in Canada and by the NBS.

The NBS Z-function is calculated for a thermometer with an $\alpha = 0.003925$ and represents a scale in use at the present time [25]. The Los and Morrison's Z-function based on the NBS Z-function has been compiled for other thermometers [26]. The maximum difference between the VNIIFTRI and the NBS scales at 80° K is of the order of 0.01°. Los and Morrison's calibration [26] has been derived from the scale and lies completely below that of the VNIIFTRI.

* We do not consider that the use of Z-functions is the best method of comparing thermometers made of different brands of platinum, especially below a temperature of 20° K. Since, however, no published data exists on direct calibration of pure platinum thermometers, we used Z-functions for their comparison.

SUMMARY

1. In establishing a temperature scale in the range of 10-90° K, four platinum thermometers ($\alpha \simeq$ $\simeq 0.003925$) were compared at 107 different temperatures with a gas thermometer which had no dead space. Comparisons were made in an adiabatic cryostat in the range of 10.7 to 94.9° K [27].

2. From the worked-up experimental data, smoothed calibration tables for $W_{ux6}(T)$ and $T(W_{ux6})$ were compiled, showing the relation of the mean relative resistance of all the group thermometers to temperature.

3. The group of four ux6 thermometers determines the practical temperature scale in the range of 10° to 90.19° K. This group serves as the primary practical standard for the scale in this range.

4. The practical scale is related to the recognized scale, which operates above the oxygen point, by means of the numerical value of this point $T_{O_2} = 90.19°$ K. If this value of the oxygen point temperature is changed, all the temperatures of the practical scale should be multiplied by the ratio $\frac{T_{O_2}}{90.19}$, where T_{O_2} is the new oxygen point temperature.

5. The practical scale is an approximation to the thermodynamic scale of temperatures. These two scales differ by the following amount:

$$T_{ther} - T_{pract} = T_{pract}\left[\frac{T_{O_2}}{90.19} - 1\right] \pm \eta + \delta.$$

6. Further tests of the thermometers showed that the reproducibility of their readings, established by mutual comparisons, is better than ± 0.002°. The variations of the thermometer readings is in any case smaller than the errors in producing reference points.

LITERATURE CITED

[1] A. S. Borovik-Romanov, M. P. Orlova, and P. G. Strelkov, Setting up a Low-Temperature Scale between 90.19 and 10° K by Means of a Calibration Table of a Group of Reference Platinum Resistance Thermometers [In Russian] (Main USSR Chamber of Measures and Measuring Instruments Press, Moscow, 1954).

[2] D. N. Astrov, A. S. Borovik-Romanov, M. P. Orlova, and P. G. Strelkov, Izmeritel'naya Tekh. No. 11 (1959).*

[3] D. N. Astrov and A. S. Borovik-Romanov, Pribory i Tekh. Eksp. No. 1 (1958).*

[4] W. Keesom, Helium [Russian translation] (IL, Moscow, 1949).

[5] F. Henning, Temperatures (1950).

[6] F. Keyes, Temperatures (1941) p. 45.

[7] Onnes H. Kammerling, Comm. Leid. (1907), 102; Comm. Leid. (1908), 102.

[8] J. Palacias and Onnes H. Kammerling, Comm. Leid (1924), 107.

[9] D. Boks and Onnes H. Kammerling, Comm. Leid. (1908), 102.

[10] L. Holborn and J. Otto, Zs. f. Phys. 30, 320 (1924).

[11] F. Penning and Onnes H. Kammerling, Comm. Leid. (1923), 165.

[12] J. Van Agt and Onnes H. Kammerling, Comm. Leid. (1925), 176.

[13] L. Holborn and J. Otto, Zs. f. Phys. 38, 358 (1926).

[14] G. Nijhoff, W. Keesom, and B. Hiin, Comm. Leid. (1927), 188.

[15] G. Nijhoff and W. Keesom, Comm. Leid. (1927), 188.

* See English translation.

[16] W. Keesom and W. Walstra, Comm. Leid. (1947), 271.

[17] F. Brickwedde andH. Hoge, J. Res. NBS (1939), 22.

[18] W. Keesom and Jansen Van Agt, Comm. Leid. (1926), 182.

[19] T. Rubin, H. Altman,and H. Johnston, J. Amer. Chem. Soc. 76, 5289 (1954).

[20] M. P. Orlova, Izmeritel'naya Tekh. No. 5 (1959).*

[21] L. Landu and I. Pomeranchuk, Phys. Zsch. Sowjet 10, 649 (1936).

[22] P. G. Strelkov, A. S. Borovik-Romanov,and M. P. Orlova, Zhur. Fiz. Khim. 28, 2 (1954).

[23] Proces-Verbaux du Comite Consultat. de Termometrie (1954), Annexe, m. 18.

[24] A. S. Borovik-Romanov, M. P. Orlova,and P. G. Strelkov, Standard Table of T = f(W) for the Temperature Range of 10-90° K [In Russian] (Standardgiz, 1959).

[25] Proces-Verbaux C.J.R.M. (1948), 21, m. 87.

[26] Los and Morrison, Canad. J. Phys. 29, 142 (1951).

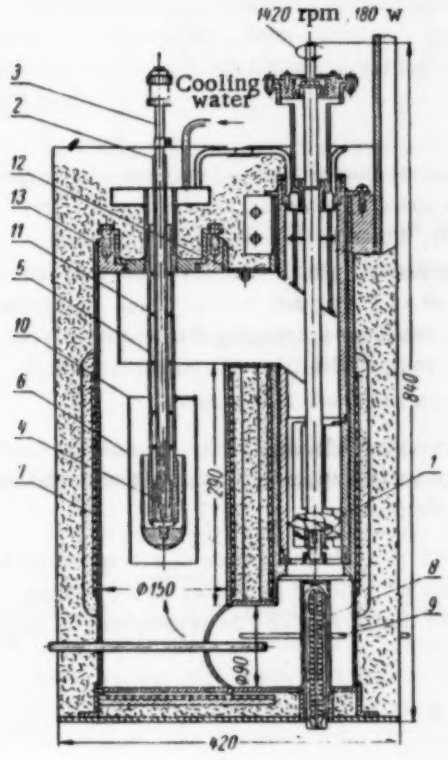
[27] D. N. Astrov, A. S. Borovik-Romanov, M. P. Orlova,and P. G. Strelkov, Izmeritel'naya Tekh. No. 11, (1959).*

* See English translation.

A LIQUID THERMOSTAT FOR HIGH TEMPERATURES

A. M. Sirota and B. K. Mal'tsev

The Physics Laboratory of the All-Union Thermotechnical Institute uses a salt thermostat, whose construction is briefly described below (see figure), for calibrating thermocouples against a resistance thermometer at 200-600° C.



A fan pump 1 pumps fused potassium nitrate (KNO_3, 53%; $NaNO_3$, 70%; and $NaNO_2$, 40%) around a closed circuit. The output of the pump is over 10 tons/hour. Thermocouple 2 which is being calibrated and the resistance thermometer 3 are placed in a copper container 4 inside a thin-walled stainless steel tube 5, which has a small thermal conductivity. The lower portion of the tube is enlarged and connected to screen 6 which contains a stationary volume of potassium nitrate. This raises the thermal inertia and smoothes out any temperature variations in the lower portion of the tube.

The thermostat heaters 7 are connected to the ac line through a ferroresonant voltage stabilizer of 5 kw. The thermostat temperature is set manually; the power of heater 8 is changed according to the readings of the thermocouple placed inside sleeve 9. Once a constant temperature is reached it is maintained at ± 0.01° C.

Since the output of the pump is large, the heat exchange between the internal wall of the thermostat and the potassium nitrate leads to only a small variation of the temperature of the latter thus ensuring the absence of any significant temperature gradients in the volume of the thermostat. The temperature distribution along the lower part of tube 5 is considerably improved due to screen 10. In order to prevent heat exchange by convection, silver screens 11 are placed at intervals across tube 5. An upward displacement by 20 mm of the resistance thermometer did not bring to light any noticeable temperature gradients.

The excess potassium nitrate formed when the thermostat temperature rises is released through the exhaust pipe 12, arranged in such a way that the level of potassium nitrate remains higher than the bottom end of flange 13 in the narrow gap between the flange and the body of the thermostat. Such a position of the level prevents the possibility of a pulsating discharge which can arise in a thermostat with a circulating liquid and two free levels.

Tube 5 which is welded to flange 13 is dismountable, thus making the thermostat easily adjustable for most varied calibration operations.

COMPENSATED SEMICONDUCTOR STABILIZERS USED AS POWERFUL SOURCES OF REFERENCE VOLTAGE

S. D. Dodik

It is shown in [1] that silicon stabilitrons with appropriate temperature compensation can serve as reference voltage sources with a stability similar to that of standard cells. These sources, however, have as yet a fairly large output resistance (2-10 ohms) and withstand small loading currents, thus limiting their application in modern group automation devices for the measurement and control of industrial processes. These devices require reference dc voltage sources of the order of 5-30 v with an output current of 1 amp and more. These parameters can be provided by compensated transistor voltage sources with silicon stabilitrons supplying the reference voltage. In this connection, the present article deals with some of the properties and peculiarities of compensated high precision semiconductor stabilizers.

The accuracy of electronic commercial measuring instruments attains 0.1%, and in this connection lasting deviations of the reference voltage used, including drift and temperature variations, should not exceed 0.02-0.05%. Such a degree of stability is of the same order as that of a grade III standard cell.

For the purpose of an analysis, let us examine the circuit shown in Fig. 1 which consists of a compensated semiconductor stabilizer with a series-connected controlling transistor and a single dc amplifier (DCA) whose collector circuit is fed from a separate source. The random instability of this device can be represented in terms of percentage by the expression:

$$\Delta\% = \sqrt{\Delta_1^2+\Delta_2^2+\Delta_3^2+\Delta_4^2+\Delta_5^2} \quad . \tag{1}$$

where Δ_1, Δ_2, Δ_3, Δ_4, and Δ_5 are relative variations of the output voltage U_0 due to variations, respectively, of the load current I_1, the supply voltage of the control transistor, U_{i1}, the supply voltage of the amplifying transistor U_{i2}, the ambient temperature, and time (on account of the drift of the stabilizer parameters).

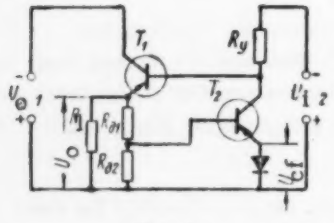


Fig. 1

In a general case Δ_1, Δ_2, and Δ_3 are respectively equal to the ratios of the permissible relative variations in I_1, U_{i1} and U_{i2} to the corresponding stabilization coefficients K_1, K_2, and K_3.

Their analysis provides the following formulas which are sufficiently accurate from the practical point of view for coefficients K_1, K_2, and K_3:

$$K_1 = \frac{R_1}{R_0} \; ; \tag{2}$$

$$K_2 = \frac{R_{K1}}{R_0} \cdot \frac{U_0}{U_{i1}} \; ; \tag{3}$$

$$K_3 = S_2 R_y \frac{n}{A} \cdot \frac{U_0}{U_{i2}} \; ; \tag{4}$$

$$R_0 = \frac{\left(\frac{R_y}{\beta_1} + \frac{1}{S_1}\right) A}{S_2 R_y n} \; . \tag{5}$$

$$A=1+r_d S_2+\frac{R_\partial S_2(1-n)}{\beta_2}. \qquad (6)$$

Here R_l is the stabilizer load resistance;

R_{k1} is the collector resistance of the common emitter controlling transistor;

R_o is the output resistance of the stabilizer;

S_1 and S_2 are the collector current slope characteristics of the controlling transistor and the dc amplifier transistor, respectively, determined as partial derivatives of the collector current with respect to the base voltage with a constant collector voltage, and equal in a system of h-parameters with a common base to h_{11} and h_{21};

β_1 and β_2 are the current amplification factors for the common emitter controlling transistor and the dc amplifier transistor, respectively;

r_d is the internal resistance of the reference voltage source;

R is the total resistance of the potential divider in the feedback circuit ($R_\partial = R_{\partial 1} + R_{\partial 2}$, Fig. 1);

$\underline{n}$ is the feedback factor equal to $\frac{R_{\partial 2}}{R_\partial}$; and

R_y is the amplifier load resistance.

In deriving these formulas neither the effect of the internal resistance U_{i1} of the source nor the collector resistance of the amplifier transistor were taken into account.

From the analysis of formulas (2) - (4), the following conclusions can be drawn.

1. It is necessary to increase the amplifier load resistance R_y as much as possible, since it improves considerably K_1, K_2, and especially K_3. From this point of view, it is advisable to increase in high precision amplifiers the supply voltage U_{i2} since an increase in resistance R_y with a constant U_{i2} leads to a decrease in the amplifier collector current and hence to a reduction in the slope S_2 of the mutual characteristic, thus worsening the parameters of the stabilizer. For dc amplifiers using P1, P2, P13-P15 transistors, R_y should be made in practice equal to 20-40 kilohms. At the same time U_{i2} should be within the limits of 100-150 v.

2. The stabilizer parameters are greatly affected by the feedback factor and the resistance of the potential divider in the feedback circuit. From this point of view, it is advisable to make the reference voltage differ but little (1-2 v) from the output voltage. Moreover, the potential divider required for a precise adjustment of the output voltage must be made with a sufficiently low resistance.

3. The output voltage is affected most by the U_{i2} voltage, which feeds the dc amplifier. Hence, it is advisable to keep it more constant than voltage U_{i1}. Considering the small current (of the order of 5 ma) taken from the source of U_{i2} it is convenient to obtain this voltage from a gas stabilizer or series-connected silicon stabilitrons.

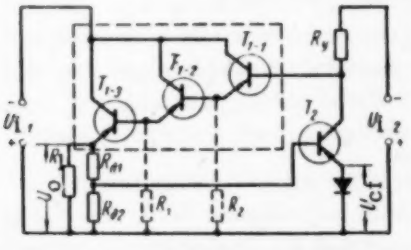


Fig. 2

In order to evaluate the effect of the input voltages and the load current let us examine the circuit of the 8-10 v, 1 amp compensated stabilizer shown in Fig. 2. This stabilizer uses for control purposes a compound transistor which can be represented in a general case by an equivalent transistor [2]. The equivalent treble compound transistor parameters, which are required for calculating the stabilization factor, can be obtained from the following formulas:

$$\beta_1=\beta_{1\text{-}1}\beta_{1\text{-}2}\beta_{1\text{-}3}; \qquad (7)$$

$$S_1=\frac{S_{1\text{-}1}S_{1\text{-}2}S_{1\text{-}3}\beta_{1\text{-}2}\beta_{1\text{-}3}}{S_{1\text{-}1}S_{1\text{-}2}\beta_{1\text{-}2}\beta_{1\text{-}3}+S_{1\text{-}1}S_{1\text{-}3}\beta_{1\text{-}2}+S_{1\text{-}2}S_{1\text{-}3}}; \qquad (8)$$

$$R_{k1}=\frac{R_{k1\text{-}1}R_{k1\text{-}2}R_{k1\text{-}3}}{R_{k1\text{-}2}R_{k1\text{-}3}\beta_{1\text{-}2}\beta_{1\text{-}3}+R_{k1\text{-}1}R_{k1\text{-}3}\beta_{1\text{-}3}+R_{k1\text{-}1}R_{k1\text{-}2}}. \qquad (9)$$

In formulas (7), (8), and (9) subscripts 1-1, 1-2, and 1-3 refer, respectively, to the low-power, medium-, and high-power transistors of the compound transistor.

Let us assume the following practical parameters for the transistors and the stabilizer:

transistor $T_{1\text{-}1}$ $\beta_{1\text{-}1}=30$; $S_{1\text{-}1}=30$ ma/v; $R_{k1\text{-}1}=40$ kilohms; (emitter current $i_e=2$ ma);

transistor $T_{1\text{-}2}$ $\beta_{1\text{-}2}=25$; $S_{1\text{-}2}=100$ ma/v; $R_{k1\text{-}2}=5$ kilohms; (emitter current $i_e=15$ ma);

transistor $T_{1\text{-}3}$ $\beta_{1\text{-}3}=40$; $S_{1\text{-}3}=2$ amp/v; $R_{k1\text{-}3}=0.3$ kilohm; (emitter current $i_e=1$ amp);

transistor T_2 $\beta_2=30$; $S_2=50$ ma/v; $i_e=3.5$ ma; $U_{out}=10$ v; $I_1=1$ amp -50%; $U_{i1}=15$ v $\pm$ 10%;

$U_{i2}=150$ v $\pm$ 0.5% with a supply voltage variation of $\pm 10\%$; $n=0.8$; $R=200$ ohms; $R_y=40$ kilohms. The source of the reference voltage is a silicon stabilitron D 808, $r_d=4$ ohms, and the stabilizer voltage = 8 v.

Let us find from (7-9) the equivalent parameters of the compound transistor:

$\beta_1=30{,}000$; $S_1=1.3$ amp/v; $R_{k1}=27.5$ ohms.

From formulas (2) - (5), we obtain $R_0=0.00157$ ohms; $K_1=6350$; $K_2=11{,}700$; $K_3=85$. Then $\Delta_1=0.008\%$, $\Delta_2=0.0009\%$, and $\Delta_3=0.006\%$.

It will be seen from the above that the total instability due to the supply voltages and the variations of the load current does not exceed 0.01%, and the instability due to voltage U_{i1} is extremely small. In fact, Δ_3 is usually smaller since the voltage of the gas-filled stabilizer with a practically constant load varies by less than $\pm$ 0.5 %. If at the same time the load current varies by only 20 % instead of 50 %, the total instability due to the load current and the feeding voltage variations will be considerably smaller than 0.01%. It follows from the above that with appropriate simple arrangements in designing the stabilizer circuit it will be possible to reduce the instability of the output voltage due to the variations of the load current and the input voltages to less than 0.01%.

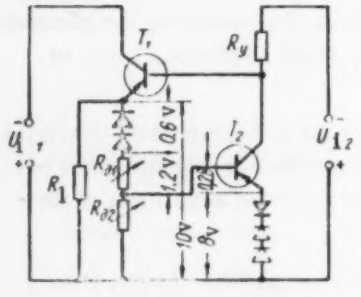


Fig. 3

Let us examine briefly the advisability of using multistage dc amplifiers. A multistage dc amplifier decreases R_0 and correspondingly increases K_1 and K_2 thus improving the stabilizing properties of the device with respect to the load current and voltage U_{i1} variations. At the same time, irrespective of the height of the amplifier gain, the stabilization factor with respect to U_{i2} is determined in the main by the gain of the dc amplifier's first stage, which functions at the same time as a stabilizer comparison circuit. In fact when U_{i2} is varied, the collector current of all the stages including the first stage must also vary. This current must change to such an extent that the additional voltage drop across the load resistance of the first stage compensates the variation in U_{i2}. At the same time a corresponding variation of the voltage between the base and the emitter of the first stage transistor will occur proportionally to the slope of the transistor characteristic, which in turn will lead to approximately the same variation of the output voltage. Moreover,

$$K_3=S_{2\text{-}1}R_{y1}\frac{U_0}{U_{i2}}\cdot\frac{n}{A},$$

where $S_{2\text{-}1}$ is the slope of the first stage transistor mutual characteristic; and

R_{y1} is the load resistance of the first stage.

From the above considerations, it would appear that in multistage dc amplifiers R_{y1} should also be made large thus requiring a large U_{i2} voltage; the U_{i2} voltage must, due to the reasons mentioned above, be stable. As far as the possibility of decreasing R_0 by means of a multistage amplifier is concerned, it is more advantageous to achieve it by increasing the number of transistors in the compound transistor circuit. In view of the above and the tendency of dc amplifiers to complicate the circuit and make it unstable, the use of multistage dc amplifiers

should be considered inadvisable in precision semiconductor stabilizers with a tolerance of 0.01% in the instability due to variations in the load current and input voltages, since such a degree of stability can be easily obtained with a single-stage dc amplifier and a compound transistor.

In designing compensated high-precision semiconductor stabilizer circuits, it is important to provide for temperature compensation. Variations in the stabilizer output voltage due to temperature variations occur for the following reasons: 1) reference voltage changes; 2) variations in the voltage between the base and the emitter of the dc amplifier transistor; 3) variations in the initial current I_{k0} of the collector and the parameters of the amplifier; 4) changes in the parameters of the compound transistor. The most important of these effects are the first two.

In [1] the temperature instability of the silicon stabilitrons type D-808 - D-813 [3] is examined in detail and methods of temperature compensation are indicated. Since the voltage between the base and the emitter of the dc amplifier transistor falls with rising temperature (approximately 2 mv per 1° C), whereas the reference voltage increases with rising temperature, this effect compensates partially for the temperature variations of the reference voltage. This, however, is insufficient to compensate for the temperature variations of a silicon stabilitron, and it is necessary to use additional compensating p-n junctions in the form of silicon or germanium diodes connected in the forward direction [1]. However, connecting compensating diodes in series with the reference voltage, as shown by a dotted line in Fig. 3, is inadvisable since the dynamic resistance of the reference source is thereby considerably increased. It is more advantageous to connect the compensating diodes into the upper arm of the potential divider, as shown in Fig. 3 [4]. Such a connection has the following advantages:

1) Owing to the small voltage drop across the compensating diodes, the current flowing through them can be made considerably larger than that through the reference stabilitrons, thus making the dissipated power in the diodes about the same as in the reference stabilitrons, which will provide temperature compensation over a wide range of temperatures (from + 20 to + 50 ° C). This compensation is due to the fact that for approximately equal dissipated power, the conditions of heat exchange in the reference stabilitrons and compensation diodes are roughly the same.

2) The dynamic resistances of the diodes are at a minimum (of the order of 1-2 ohms per diode) when large currents (20-30 ma) are flowing through them.

3) Under these conditions, instead of the emitter current flowing through the compensating stabilitrons, it is the base current of the dc amplifier transistor that flows through them, thus reducing to $1/\beta_2$ the instability due to the dynamic resistance of the compensating diodes.

4) By controlling the current through the compensating diodes it becomes possible to attain an accurate temperature compensation which affects the general temperature instability.

The effect of temperature on the output voltage due to the variation of the remaining parameters of the controlling and amplifying transistors, including the variations of the initial collector current I_{k0}, is considerably smaller than the effect discussed above. These variations are decreased by the feedback circuit and are normally more than an order lower than the variations in U_0 due to changes in the amplifier transistor base-emitter and the reference voltage circuits. These variations are, and always can be, dealt with under a general temperature compensation. Generally speaking, an accurate temperature compensation, due to nonlinear temperature coefficients, can only be attained at one temperature. In practice, however, with an accurate compensation at T = + 20 to 25° C it is possible to obtain optimum compensation of the order of ± 0.001% in the range of + 10 to 50° C. Moreover, it is very important for the reference stabilitrons, the compensating diodes, and the dc amplifier transistors to be under the same temperature conditions and sufficiently far removed from heat-radiating components. It is best to place these elements in a separate small compartment made of insulating material.

A preliminary calculation of temperature compensation can be attained by assigning, as it was pointed out in [1], one of the compensating diodes to the base emitter circuit of the amplifier transistor. This calculation, however, cannot ensure satisfactory compensation owing to the individual difference between stabilitrons and compensation diodes. Hence, the temperature compensation adjustment has to be achieved experimentally. This is done in the following manner. At first, thermocompensation is calculated for a current in the compensating diodes which produces a dissipation power roughly equal to that of the reference stabilitrons. If the compensation proves to be of the order of 1.5 -2 mv per 1° C too high, or too low, one of the compensating diodes has to be taken

away or added. When the compensation is too low or too high by an amount smaller or equal to 0.5 mv per 1° C the current through the compensating diodes is respectively either increased or decreased by means of resistor R_2 (Fig. 3) until the required compensation is obtained. When this adjustment is made, it is advisable to have in stock a few compensation diodes with known temperature compensation at various currents. This procedure provides a rough regulation by means of changing the diodes and a final adjustment by means of setting the current. A precise setting of the output voltage is achieved by varying within small limits the upper arms of the potential divider ($R_{\partial 1}$ in Fig. 3 circuit). With a certain amount of experience the thermocompensation procedure presents no difficulties and, in our opinion, can even be used in mass-production testing of semiconductor compensated stabilizers used as powerful sources of reference voltages. We have already stated that by this means it is easy to obtain compensation of the order of $\pm$ 0.001%, thus approaching the temperature stability of grade III standard cells.

For the stabilizer in question with $U_O = 10$ v, $I_l = 1$ amp, temperature compensation = 0.001% per 1° C, and the same temperature variation tolerances as for a grade III standard cell $(20\ ^{+20}_{-10})$° C, the maximum temperature instability will be $\Delta_4 = \pm$ 0.02%.

Semiconductor compensated stabilizers can have a drifting output voltage due to temperature changes and to variations with time of the parameters of the controlling transistors, dc amplifier transistors, silicon stabilitrons, thermocompensating diodes, and to variation of the voltage between the base and the emitter of the amplifier transistor. The drift due to the controlling transistors is reduced to hundredths of its original value by the feedback circuit and can be neglected in practice. The drift of the feedback potential divider can also be neglected if it is made of highly stable wire-wound constantan or manganin resistors.

Tests [1] have shown that the total drift in the stabilizer during three months was less than 0.01%. At the same time, it is known [5] that the drift with time of silicon stabilitrons does not exceed 0.002% during 5000 hours. Measurements of the drift in the voltages between the base and the emitter of the amplifier transistor and across the thermocompensating diodes showed that these voltages remain constant during three months in the limits of 0.01-0.03%. Taking into consideration that the absolute value of these voltages is considerably smaller than that of the reference voltage, the relative drift of the output voltage due to the drift in the parameters of these elements should amount to 0.002-0.003%. On this basis, it is possible to consider that the drift with time does not exceed 0.003-0.005% during several months.

Let us now examine qualitatively the basic effects of this mode of operation.

When the load current is changed (increased) the following effects are produced:

a) U_O falls due to a fall in the voltage across the output resistor R_O caused by stabilization factor K_1;

b) the controlling transistor temperature rises and its resistance R_{k1} decreases thus leading to a rise in U_O;

c) S_1 increases, making R_O smaller and correspondingly increasing U_O;

d) β_1 decreases, thus increasing R_O and decreasing U_O;

e) the voltage between the base and the emitter of the controlling transistor drops and the base current of the controlling transistor decreases, thus leading to a rise in the collector current of the amplifier transistor and a corresponding increase in U_O;

f) due to a general rise of the voltage on the controlling transistor base, the voltage on the collector of the amplifier transistor rises, thus raising the temperature of this transistor. At the same time, due to a decrease in the total current through the amplifier transistor its temperature decreases. As the result of both tendencies, the temperature of the amplifier transistor can either rise or fall depending on the relation of the currents and voltages, and produce either a rise or fall in U_O. In practice, it is possible to consider that the two factors compensate each other.

Finally, changes in the mode of operation of the controlling transistor due to variations in the load current lead to smaller changes in U_O than would have occurred if the mode of operation were not affected.

A change (increase) in U_{i1} produces the following effects:

a) U_O increases due to the final resistance R_{k1} which is affected by the stabilization factor K_2;

b) R_{k1} decreases due to the rise in the temperature of the controlling transistor, thus producing an additional rise in U_o;

c) due to the rise in the temperature of the controlling transistor, the voltage between the base and the emitter of the controlling transistor falls and the current in the controlling transistor base decreases, thus raising the current in the collector of the dc amplifier transistor and producing a corresponding rise in U_o;

d) owing to a decrease in the total voltage across the controlling triode base, the voltage across the collector of the amplifier transistor falls, thus lowering the temperature of the transistor. At the same time, due to the increase in the total current through the amplifier transistor the temperature of this transistor rises. As the result of these two tendencies and the relation between the currents and voltages in the circuit the temperature of the amplifier transistor can either rise or fall, thus either increasing or decreasing U_o. It is possible to consider that in practice, the two effects cancel each other.

The final effect of the changes in the mode of operation due to variations in U_{i1} is an increase in the variations of U_o. Since the stabilization factor K_2 is large, the basic variation in U_o due to U_{i1} is caused by the change in the operating conditions, especially those of the controlling transistor. This effect can produce an instability due to the variations in U_{i1}, many times greater than K_2. In order to reduce this instability it is necessary to lead away heat from the powerful composite transistor by using for the purpose special heat conductors, and to select for the low-power component transistors operating conditions which would produce small changes in temperature with variations in the mode of operation. For the same purpose, it is advisable to pass small additional stabilizing currents through the low and medium-powered transistors of the compound transistor by means of resistors R_1 and R_2, as shown by a dotted line in the Fig. 2 circuit.

A change (increase) in U_{i2} produces the following effects:

a) U_o increases due to a rise in the collector current of the amplifier transistor produced by the stabilization factor K_3;

b) owing to a rise in current and a small rise in the voltage of the collector of the amplifier transistor, the transistor temperature rises, thus leading to a fall in the voltage between the base and the emitter of the amplifier transistor and a corresponding decrease in U_o;

c) owing to a rise in the collector current of the amplifier transistor, a small increase in the slope S_2 of the characteristic occurs and decreases the initial rise in U_o;

d) owing to a small rise in the temperature of the amplifier transistor the collector voltage effect, which was previously neglected, increases and makes the voltage between the base and the emitter of the amplifier transistor drop a little, thus decreasing U_o.

The final effect of changed operation conditions of the amplifier transistor due to variation of U_{i2} is a decrease in the initial variations of U_o. Since U_{i2} remains, from the point of view of the operating conditions, practically constant ($\pm$ 0.5%), the variations of the operating conditions due to changes in U_{i2} can be neglected in practice.

In practice, the total drift in U_o, including the drift due to changed operating conditions, lies in the limits of 0.005 to 0.01%. Assuming Δ_5 = 0.01%, we find the random error:

$$\Delta\% = \sqrt{0.008\%^2 + 0.0009\%^2 + 0.006\%^2 + 0.02\%^2 + 0.01\%^2} \simeq$$
$$\simeq 0.025\% .$$

From the figures quoted above, it will be seen that instability is largely due to temperature variations. Hence, a considerable improvement in stability can be obtained by thermostatic control of the temperature of the reference voltage source, the compensation diodes, and dc amplifier transistors within $\pm$ 1 to 2° C. This will reduce Δ_4 to one-tenth or less. Moreover, in order to increase stability, it is advisable to stabilize the main voltage within $\pm$ 1 %. This measure will sharply reduce drift and consequently Δ_5, and will raise the stability of U_{i1} and U_{i2}, thus reducing Δ_2 and Δ_3. If at the same time the load current does not change by more than 10% it is possible to obtain a total instability of the device of the order of 0.01-0.005 %.

It should be noted that instability due to voltage pulsations was not taken into account, since it can be made arbitrarily small by using appropriate filters and a correct construction.

In conclusion, let us examine a practical stabilizer circuit for a 10 v, 1 amp output (Fig. 4).

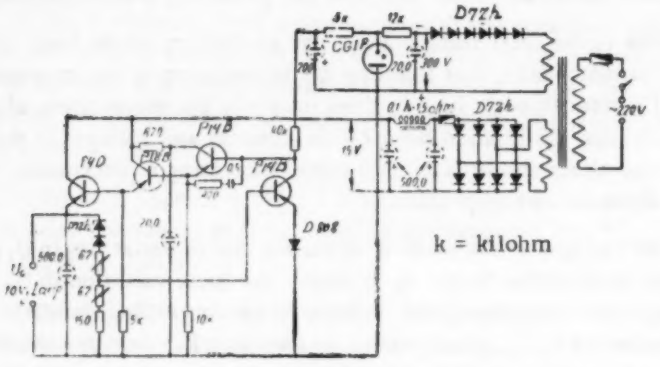


Fig. 4

This stabilizer uses the same transistors and sources of reference voltage as the circuit dealt with in Fig. 2. The RC network connected in the base circuit of transistor T_{1-1} serves to prevent oscillations from arising in the stabilizer. The same purpose is partly served by the large capacitance which shunts the load. The resistance in the transistor T_{1-1} collector circuit serves to limit the current passing through the controlling transistor during short-circuiting. The resistances of the feedback potential divider are wire-wound with constantan or manganin wire thus eliminating the effect of temperature on the feedback factor set by the potential divider resistors. The lower variable resistor of the divider serves to adjust the precision thermal compensation, and the upper one permits accurate setting of the output voltage. It is best to use for thermal compensation stabilitrons of any type connected in the forward direction. In an extreme case germanium junction diodes type D7 can be used.

The stabilizer shown in Fig. 4 provides, with correct adjustment, the following parameters:

The output voltage changes by ±0.005% with a line voltage variation of ± 10%, by ± 0.008% with a load current reduction of 50%, and by ± 0.02% with temperature variations of (20^{+20}_{-10}) ° C;

the output voltage drift for one month is 0.01%;

the output voltage attains a steady state with an accuracy of 0.02% in 5 minutes.

It should be noted that high-precision semiconductor stabilizers with circuits similar to the above can be made for higher output currents up to 20 amp.

SUMMARY

Compensated semiconductor stabilizers can provide for output currents of 1 amp and over an output voltage stability comparable to that of standard grade III cells. Such stabilizers can serve as sources of reference voltages in group automation measurements of industrial processes, in checking of measuring instruments, and in all the cases where a highly stable voltage and a large output current are required.

LITERATURE CITED

[1] S. D. Dodik, Izmeritel'naya Tekhnika No. 6 (1959).*

[2] Information Bulletin [In Russian] (Soviet Radio Press, 1955), No. 22 (210).

[3] Radio No. 11, pp. 59-60 (1958).

* See English translation.

[4] S. D. Dodik, Author's Certificate No. 124,009 dated December 25, 1958.

[5] K. Enslein, IRE Transactions on Instrumentation 1-6, 2 (1957).

A METHOD OF DESIGNING SINGLE-ENDED SELF-STABILIZING DIRECT-COUPLED INSTRUMENT AMPLIFIERS

V. A. Baramidze and I. G. Gol'dreer

Increasing the sensitivity and input impedance of dc voltage-measuring instruments (or decreasing the input impedance of current-measuring instruments) involves great difficulties both of a design and manufacturing nature.

The sensitivity of the measuring instruments can be raised and their impedance altered to suit that of the object of measurement by means of instrument amplifiers which satisfy definite technical requirements with respect to precision, stability, and maintenance of their characteristics independent of external effects.

Electronic direct-coupled amplifiers, which as it is known have inherently unstable output voltages (currents), are normally used as dc instrument amplifiers. The initial operating conditions of such an amplifier may be outside the working characteristic of its component tubes. Its output voltage drift is mainly due to that of its first stage. The random voltage variations of a direct-coupled amplifier may be both relatively rapid and very slow.

The relatively rapid variations of the output voltage are mainly due to the instability of the supplies, which produce changes in the direct components of the initial voltages and currents of the amplifiers.

The very slow variations of the output voltage are due to the so-called cathode drift which is caused by the instability of the cathode emission.

In view of the above considerations, the anode and heater supplies of multistage direct-coupled amplifiers are fitted with compensated voltage stabilizers, which,however,cannot in many cases provide the required stability of operation.

Thus, raising the stability of direct-coupled amplifiers has become a pressing problem.

One of the methods of raising the stability of such amplifiers is the use of self-stabilizing circuits, which possess the property of weakening the dependence of the output voltage on the supply voltage variations.

Self-stabilizing direct-coupled amplifiers are characterized by a quick response and a simple circuit.

Modern designs of self-stabilizing amplifiers usually involve various push-pull and balancing circuits. In practice, the effect of anode voltage variations in a push-pull circuit is decreased to one-tenth. An essential defect of these circuits, however, is the difficulty in adjustment and selection for the balanced stages of tubes with identical characteristics.

In order to explain the operation of single-ended self-stabilizing amplifiers, let us compare an anode-loaded triode amplifier circuit (Fig. 1 a) with that of a simplest parametric stabilizer which uses a stabilivolt (Fig. 1 b) and the volt-ampere characteristics of the triode and the stabilivolt (Fig. 1c and d).

Considering the triode as a nonlinear resistance of the type of R_U and comparing the two circuits (Fig. 1a and b) it is possible to arrive at the conclusion that the triode amplifier circuit possesses stabilizing properties: the relative variations of the output voltage of such a circuit are always smaller than those of the anode supply.

Hence, a stage with an anode load can be considered as an amplifier with a parametrically self-stabilized output voltage. It can be called, therefore, a controlled parametric voltage stabilizer. The level of output voltage U_{a_0} stabilization changes by ΔU_{a_0} when the grid bias voltage E_{g_0} changes by ΔE_{g_0}, which is equivalent to feeding to the circuit an input signal $U_i = \Delta E_{g_0}$. This reasoning is clearly demonstrated by the experimental curve of the relation of output voltage U_{a_0} to the anode supply voltage U_{asp} for tube 6N1P, shown in Fig. 2. It will be seen from the same curve that the output voltage self-stabilization factor p of a stage with anode loading increases with a rising bias voltage E_{g_0}.

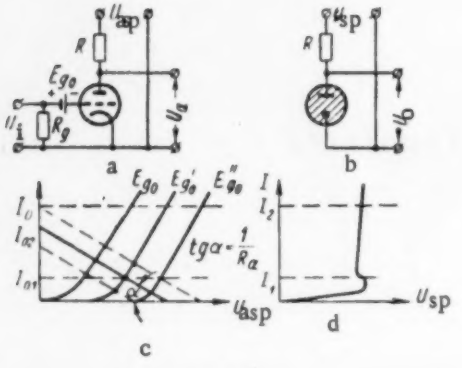


Fig. 1

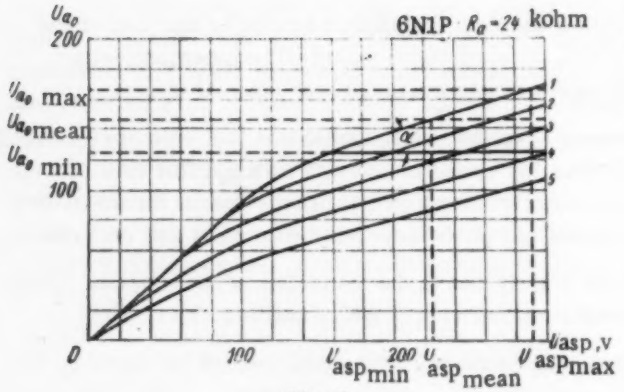


Fig. 2

1 – E_{g_0} = –2.5 v, p = 2.34; 2 – E_{g_0} = –2.0 v, p = 2.05; 3 – E_{g_0} = –1.5 v, p = 1.86; 4 – E_{g_0} = –1.0 v, p = 1.77; 5 – E_{g_0} = –0.5 v, p = 1.44; $U_0 = f(U_{asp})$.

$$p = \frac{\dfrac{\Delta U_{asp}}{U_{asp\ mean}}}{\dfrac{\Delta U_{a_0}}{U_{a_0\,mean}}}.$$

Automatic biasing in the circuit of Fig. 1a would produce a current negative feedback. This feedback would lead to greater linearity in the tube resistance and thus to a lowering of its self-stabilizing properties.

The utilization of the nonlinear characteristic of tubes in designing self-stabilizing amplifier circuits will be effective if the quality Q of the nonlinear resistance, which in this case consists of the tube, is sufficiently high. It will be seen from Fig. 2 that single-ended triode amplifying stages usually reduce the instability of the output voltage due to the anode supply voltage variations only to one-half.

The self-stabilization of a stage with an anode load can be greatly increased by feeding to the grid an auxiliary signal which varies according to a definite law when the anode supply voltage U_{asp} changes. The variations of the auxiliary voltage should act on the input of the circuit in phase with the variations of the anode voltage.

The circuits of single-ended self-stabilizing amplifiers [1] are based on this principle. They possess, as compared with push-pull and balanced circuits, a number of advantages: ease of adjustment; the possibility of using tubes without preselection; and elimination of electronic voltage stabilizers (in especially sensitive circuits the simplest high-speed parametric stabilizers should be used).

The basic unit of single-ended self-stabilizing amplifiers in question consists of a double self-stabilizing stage (Fig. 3). The use of this unit provides an output voltage largely independent of the anode supply voltage variations over a wide range.

The cathode follower, which feeds the controlling voltage ΔU_k to the grid of the following tube, also serves to provide a high input impedance for the amplifier.

Let us now examine the principle of operation of the self-stabilizing unit (Fig. 3).

Variations of the anode voltage produce variations in voltage U_k at the output of the cathode follower, and hence at the grid of the second half of the tube ($U_k - E_{g_0}$). As the result of this the internal resistance of this half of the tube changes in such a manner that the dc component of the output voltage remains practically constant.

The principle of operation of a self-stabilizing unit can also be demonstrated by means of plotting the dynamic characteristics of the second stage tube. When the anode voltage U_{asp} increases, the dynamic characteristic of this tube is displaced upwards parallel to itself.

At the same time the dc component of the cathode follower output voltage U_k also increases. The difference $(U_k - E_g)$ becomes more positive, thus displacing the working point upwards along the characteristic.

The latter effect in turn leads to the stabilization of the output voltage dc component U_a (owing to the rise in the voltage drop U_{R_a} across resistor R_a).

Tests have shown that the self-stabilizing circuit retained with different tubes its stabilizing properties in the range of U_{asp} variations of 200 to 300 v. The self-stabilizing property of the circuit is preserved with various input voltages and provides a linear relationship of $U_a = f(U_i)$. The self-stabilization factor with respect to the anode voltage variations is $p \simeq 150$ to 180.

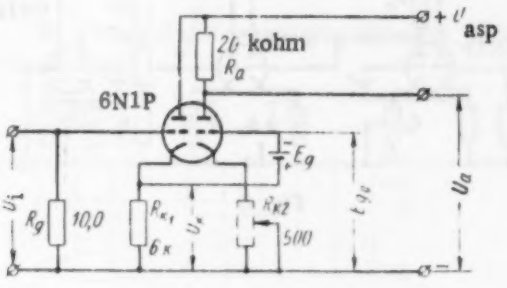


Fig. 3

$E_g = 6$ v; $|E_g| < |U_k|$; $E_{g_0} = U_K - E_g$.

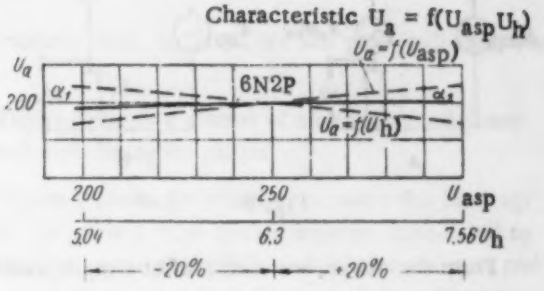


Fig. 4. $\alpha_1 = \alpha_2$, $\tau_h \simeq \tau_{asp}$ } conditions of adjustment of the self-stabilizing element; τ_{asp} is the anode circuit time constant including the rectifier filter and the lag in the rectifiers; $\tau_h \simeq 1.5$-2 sec is the temperature lag of the tube cathodes.

By selecting voltages E_g and U_k it is possible to obtain a relationship $U_a = f(U_{asp})$ which has a dropping characteristic. If resistance R_{k2} is added to the circuit, relation $U_a = f(U_{asp})$ will attain a rising slope, since resistance R_{k2} provides a negative current feedback which lowers the self-stabilizing properties of the second stage tube. The addition of resistor R_{k2}, however, provides a more accurate alignment of the first and second stages, thus leading to higher self-stabilizing properties of the circuit as a whole.

When the heater voltage of the tube is changed (for instance from 5 to 7 v), with $U_{asp} = \text{const}$, the relation $U_a = f(U_h)$ (where U_h is the heater voltage) has a falling slope characteristic.

If the anode circuits are fed from a rectifier and the heaters directly from the ac supplies, it is possible to make, by means of special adjustments, the output voltage independent of the line voltage variations. The method of such an adjustment is shown in Fig. 4. The essence of the method consists in adjusting characteristic $U_{a_0} = f(U_{asp})$ by means of the variable resistor R_{k2} in such a manner that it acquires a rising slope whose angle α_2 is equal to the falling characteristic angle α_1. Under this condition simultaneous proportional variations of the anode and the heater voltages, which occur in normal operation, are mutually compensated. In order to compensate for sudden line voltage variations (with a constant mean value) the unit should be adjusted to compensate for the anode voltage variations only. This effect is due to the cathode emission lagging behind the sudden line voltage changes.

If the supply circuit has both slow and rapid voltage variations, the self-stabilizing elements should be adjusted in such a manner that the output voltage is independent both of the anode and heater voltage variations. Moreover, it is necessary to make the time constants of the anode and heater voltages the same.

Another useful property of the self-stabilizing elements consists in their smoothing out of the supply voltage pulsations.

Let us derive the conditions for an ideal compensation of a two-stage self-stabilizing unit output voltage (Fig. 3) against anode voltage variations.

An equivalent circuit of a cathode follower (with respect to ac) whose anode circuit is fed from an unstabilized dc supply $U_{asp} \pm \Delta U_{asp}$ is shown in Fig. 5a. We can deduce from it that

$$\Delta I_a = \frac{\Delta U_{asp} - \mu_1 \Delta U_K}{R_{i1} + R_K},$$

where ΔU_{asp} is the variation of the anode voltage;

ΔI_a is the corresponding variation of the anode current; and

ΔU_k is the corresponding variation of voltage U_{k_0}.

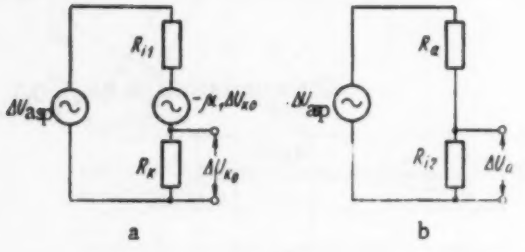


Fig. 5

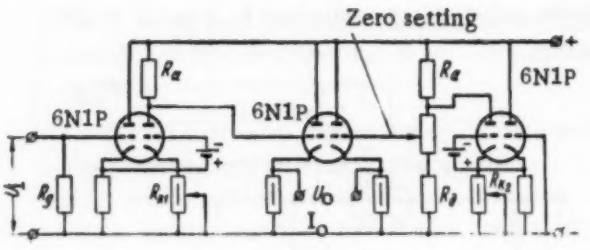


Fig. 6

From the above, we obtain after simple transformations:

$$\Delta U_K = \frac{\Delta U_{asp} R_K}{R_{i1} + R_K (1+\mu)}.$$

The equivalent circuit of the stage with the anode load appears in the second stage of the self-stabilizing element, as shown in Fig. 5b. It follows from this circuit that

$$\Delta U_a = \frac{\Delta U_{asp} R_{i2}}{R_a + R_{i2}}.$$

Then the transfer constant K_k of the anode voltage variations at the output of the first stage will be

$$K_K = \frac{\Delta U_K}{\Delta U_{asp}} = \frac{R_K}{R_{i1} + R_K (1+\mu_1)},$$

and the transfer constant K_a at the output of the second stage will be:

$$K_a = \frac{\Delta U_a}{\Delta U_{asp}} = \frac{R_{i2}}{R_{i2} + R_a}.$$

The condition of an ideal self-stabilization is expressed by the equation:

$$K_K K = K_a,$$

where K is the amplification factor of the stage with the anode load. Substituting the values of K_a, K, and K_k we shall obtain after simple transformations:

$$S_2 = \frac{R_{i1} + R_K (1+\mu_1)}{R_K R_a},$$

where S_2 is the mutual conductance of the second stage tube.

If $R_K(1+\mu_1) \gg R_{i1}$ and $\mu_1 \gg 1$, then

$$S_2 \simeq \frac{\mu_1}{R_a}.$$

If the value of resistor R_k is given, it is possible to obtain from the above a formula for calculating the value of resistance R_a:

$$R_a = \frac{R_{i1} + R_k (1+\mu_1)}{S_2 R_k}.$$

or

$$R_a \simeq \frac{\mu_1}{S_2}.$$

The value of resistor R_k for a given R_a can be calculated from formula:

$$R_k = \frac{R_a}{S_2 R_a - (1+\mu_1)}.$$

By means of self-stabilizing elements, it is possible to construct both single-ended and push-pull multistage dc amplifiers.

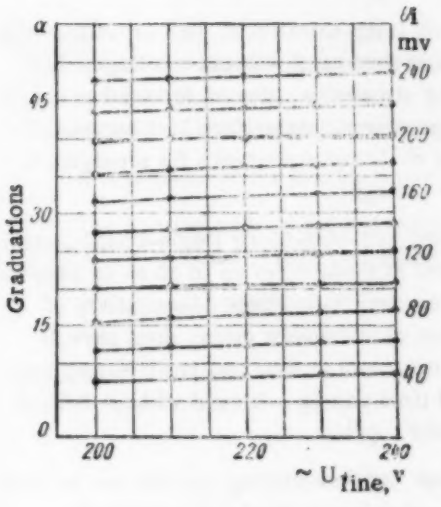


Fig. 7

U_{asp} $U_h = f(U_\sim)$.

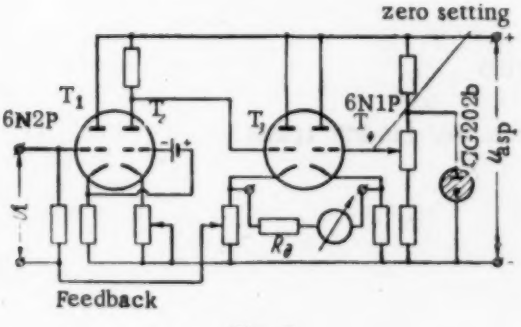


Fig. 8

Figure 6 shows a circuit of an unbalanced three-stage self-stabilizing amplifier.

Figure 7 shows the relation between the readings of a 250 μv grade 1 M24 microammeter connected to the amplifier output through a multiplying resistor, and the line voltage. A full deflection of the microammeter was produced by an input voltage of $U_i = 250$ mv; the amplifier input resistance was $R_i = 10$ meg.

It will be seen from Fig. 7 that the readings of the output instrument vary only by ± 0.3% for line voltage variations of ± 10%. The amplifier had in these tests a gain of K = 22.

The devices were tuned for maximum self-stabilization in the following manner.

The ac supply voltage feeding the rectifier was varied by means of a "Latr" autotransformer. The heating of the tubes was thus also changed, since the heaters were supplied from the rectifier power-transformer winding. A minimum variation of the microammeter readings at the output of the amplifier was attained by means of potentiometers R_{k1} and R_{k2}.

The zero drift of the amplifier during one hour and considerable variations of the supply voltage did not exceed 0.3 of a microammeter graduation.

It should be noted that the dc component of the output voltage U_o was compensated by means of a self-stabilizing element described in this article. This compensation can also be achieved by other means. For this purpose, for instance, the simplest stabilizers using stabilivolts can be used. Figure 8 shows a schematic of a self-stabilizing unbalanced amplifier which uses this type of compensation. This circuit also shows how a voltage negative feedback can be used in self-stabilizing unbalanced amplifiers. The use of this feedback stabilizes still further the dc component of the amplifier output voltage, raises the stability of the amplifier gain, and increases its input impedance by a factor of $K\beta$ (where β is the feedback coefficient).

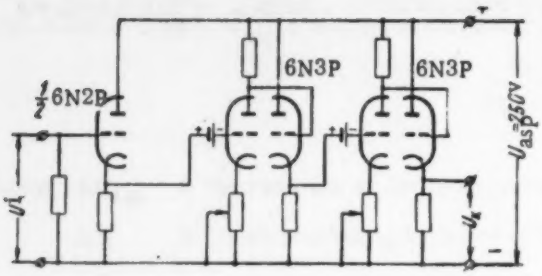
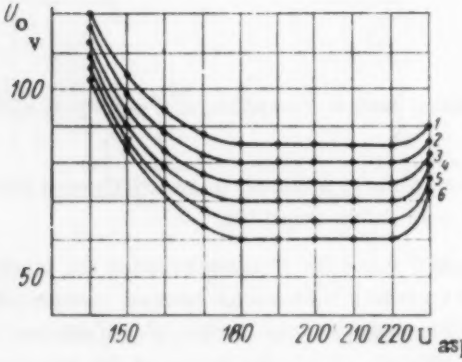


Fig. 9



U_{sig}, mv	No. of curve	U_{sig}, mv	No. of curve
0	1	−120	4
−40	2	−160	5
−80	3	−200	6

Fig. 10

Figure 9 shows a schematic of a five-stage self-stabilizing amplifier which consists of two self-stabilizing elements, and Fig. 10 shows the characteristics of these units with respect to the anode voltage variations which produce no changes in the amplifier output voltage and preserve the linear relation $U_o = f(U_i)$ when the anode supply voltage U_{asp} changes from 180 to 220 v.

Such stability cannot be obtained from existing multistage balanced amplifiers.

The gain of the amplifier (Fig. 9) is seen from the curves in Fig. 10 to be $K = 125$.

The use of additional sources of biasing in order to obtain the difference $(U_k - E_g)$ is the basic condition for stabilizing unbalanced self-stabilizing circuits.

Flash lamp batteries or mercury oxide cells can serve as sources of reference voltage. Self-stabilizing circuits can also be designed to use the simplest parametric stabilizers, for instance, gas-filled or silicon stabilivolts for supplying the reference voltage.

These self-stabilizing single-ended amplifiers can be used at frequencies up to 50 kc in addition to dc. Moreover, a threshold of sensitivity of several tens of microvolts during short periods (2-5 minutes), and several millivolts during long periods of time can be achieved without the use of stabilized supplies.

These self-stabilizing circuits can be used for constructing highly stable dc instrument amplifiers, and dc tube voltmeters and as attachments to recording instruments (for instance, to the loop oscillograph MPO-2, recorders N-16, N-270, etc.), for the purpose of raising their sensitivity and input impedance.

LITERATURE CITED

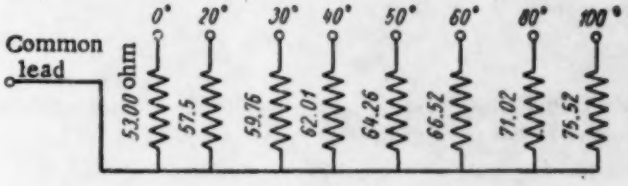
[1] V. A. Baramidze and I. G. Gol'dreer, Author's Certificate No. 115,978 (1958).

A MINIATURE RESISTANCE BOX FOR CHECKING RATIO METERS AND BRIDGES

P. A. Griban'

The resistance box made by us consists of an aluminum case of 115 x 55 x 36.5 mm, weighing 400 g and made in two equal halves.

Each half carries on an ebonite panel nine resistances mounted in a row. Thus, one body contains in effect two boxes.



One of the panels carries resistances with values corresponding to temperatures of 0-100° C for copper resistance thermometers (calibration 2 amp, 53 ohms at zero), and the other with values corresponding to temperatures of 0-200° C for platinum resistance thermometers (calibration 11 amp, 46 ohms at zero).

A schematic of the box (calibration 2 amp) is shown in the figure.

The starting ends of the resistance windings are soldered to a common lead and the other ends to terminals. The winding is made of 0.15 mm PÉSh wire (enamelled silk-covered wire).

We have sucessfully used this box for checking ratio meters and bridges on the spot.

APPLICATION OF A WAVEGUIDE BRIDGE FOR MATCHING DETECTOR AND GENERATOR SECTIONS

A. N. Akhiezer and A. I. Brodskii

In the suggested method of matching detector and generator sections a waveguide bridge consisting of an unmatched double T-joint is used. The peculiarities of the method consist in the accuracy of matching and the frequency range depending practically only on the quality of the standard load.

The matching is achieved as simply as with a phase shifter.

The instrument consists of an unmatched double T-joint (Fig. 1), whose side arms contain the standard load A and the tuning load with transformer T. A detector section is connected to arm E, and the uhf generator with a decoupling attenuator D is connected to arm H. Detector B, which it is required to match, can be used for tuning the instrument, or if the generator output is required to be matched, the generator can be used for tuning. The load in arm 1 is adjusted by means of transformer T until the indicator in arm E reads zero. The tuning is carried out at the frequency to which it is intended to match the detector or the generator output. In this connection, the instrument can be used as a comparator [2] for matching loads connected to arm 2 instead of load A.

In order to match the detector section, load A is disconnected and replaced by detector B, which is to be matched. A short-circuiting piston C is connected

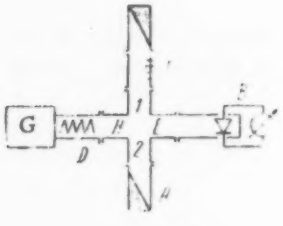


Fig. 1

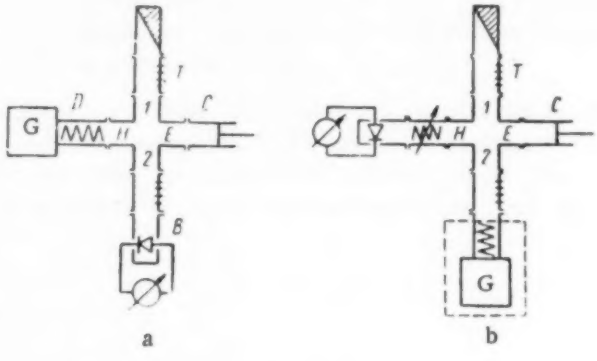


Fig. 2

to arm E (Fig. 2a). When arm H is fed a unitary amplitude wave, detector B receives a wave $\underline{a}$ of amplitude $\sim \frac{1}{\sqrt{2}}$. The wave which is reflected from the detector is divided between arm H, where it is absorbed by attenuator D, and arm E.

Half the energy reflected from the piston is absorbed by the load of arm 1* and the other half reaches detector B in the form of a wave with amplitude $|ka\,\Gamma_\partial|$ (here Γ_∂ is the reflection factor of the detector) and is added to the primary wave $\underline{a}$. When piston C is displaced, the phase of the reflected wave changes and the amplitude of the resultant wave varies in the limits of

* More accurately, the sum of the wave reflected from load 1 and the wave which has reached, owing to asymmetry, arm H directly, is equal to zero.

$$|a| \pm |\kappa a \Gamma_{\partial}| = |a|(1 \pm |\kappa \Gamma_{\partial}|). \quad (1)$$

By analyzing the dissipation matrix of the six-terminal network 2-H-E (see Fig. 1), it is possible to find that $|k| \simeq 1/2$. Moreover, if a square-law detector is used, voltage standing-wave ratio $\simeq \frac{I_{\partial\,max}}{I_{\partial\,min}}$, where I_{∂} is the detector current.

By using the matching elements of the detector section a constant indication of the detector (or a minimum change) is achieved while the piston is being displaced, thus showing that matching has been attained.

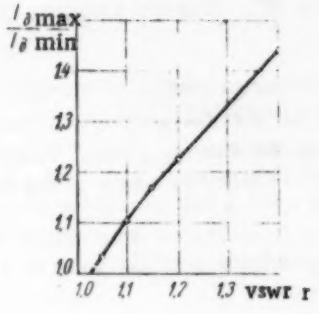


Fig. 3

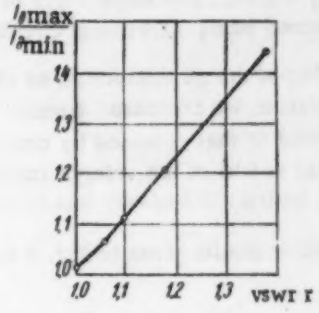


Fig. 4

In order to match the generator section, load A is disconnected and replaced with the generator * which it is required to match.

The shorting piston is connected to arm E (Fig. 2b) Detector B with a continuous attenuator, which protects the detector from overloading when the power of the tested generator is large, is connected to arm H.

The wave transmitted from the generator is divided between arms H and E. The wave reflected from piston C can reach arm H only if it is reflected a second time from the generator output. Thus, in addition to wave a which reached the detector directly, wave $ka\Gamma_g$, where Γ_g is the reflection ratio at the generator output, also reaches the detector. The phase of this wave depends on the position of piston C, and the amplitude of the resultant wave varies with the position of the piston in the limits of

$$|a|\,(1 \pm |\kappa \Gamma_g|), \quad (2)$$

moreover, as before $|k| \simeq 1/2$, i.e., the voltage standing wave ratio is $\frac{I_{\partial\,max}}{I_{\partial\,min}}$.

By using the matching elements at the output of the generator section, constant detector readings are obtained (or minimum variations) while the piston is being displaced, thus showing that matching has been attained.

A test was carried out on a wave of 3.2 cm. A generator type 51I was used as the source of power. The double T-joint, piston, detecting section, and load were taken from a 52I set. For matching the loads and balancing the T-joint and detector section (or the generator) compact four post transformers were used, but it is possible to use the 52I type transformers. A highly sensitive galvanometer with a light indicator was used as an indicating instrument. For measuring purposes an IVLU-140 line with a standard load matched to it up to a voltage standing-wave ratio of 1.01-1.02 was used. If an accuracy of matching of 1.05 is sufficient, it is possible to use standard load ÉAV, which is supplied with the IVLU-140 line. The double T-joint was balanced as described above.

* It is assumed that the generator contains a decoupling attenuator which eliminates any appreciable effect of the load on the frequency or output of the generator.

After the completion of the detector section balance $\frac{I_{\partial\,max}}{I_{\partial\,min}} < 1.02$ in the manner described above, an additional transformer, previously tuned on the measuring line to a known voltage standing-wave ratio $\underline{r}$, was inserted between the arm 2 and the detector section. (The additional transformer was connected, with the matched load attached to its output, to the measuring line, and by depressing one of its posts was adjusted to the required voltage standing-wave ratio.)

The relation of $\frac{I_{max}}{I_{min}}$ to $\underline{r}$ obtained experimentally in the interval of $1.06 \leq r \leq 1.4$ is shown in Fig. 3. Within the accuracy of measurements, this relationship is linear. By continuing it to its intersection with the X-axis, we find $r_0 = 1.02$. The slope angle of the straight line is equal to 48°. Thus the accuracy of matching is equal to the measured value (1.02) and coefficient $k = 0.55$.

The matching of the generator can be checked directly by the well-known method of a measuring line and shorting piston. Hence, we compared directly the voltage standing-wave ratio at the generator output obtained by the bridge method to that obtained by means of the measuring line and the shorting piston. This comparison was repeated for several values of the voltage standing-wave ratio, which were obtained by means of the additional transformer.

The comparison results given in Fig. 4 show that the accuracy of agreement is of the order of 1.01. Coefficient $k = 0.57$.

Thus the voltage standing-wave ratio at the matched output of the generator or the matched input of the detector section does not exceed in the above tests the value of 1.1.

LITERATURE CITED

[1] L. N. Bryanskii, Izmeritel'naya Tekhnika No. 2, (1958).*

[2] A. F. Pomeroy, Precision measurement of impedance mismatches in a waveguide, Bell. Syst. Tech. Journ. 26 (July, 1947).

* See English translation.

THE EFFECT OF TEMPERATURE VARIATIONS ON THE CHARACTERISTICS OF ANALYTICAL BALANCES

S. L. Kal'manovich and A. P. Efremov

During transportation and storage by the consumers, the adjusted and checked analytical balances may be subjected to temperature variations of ± 50° C.

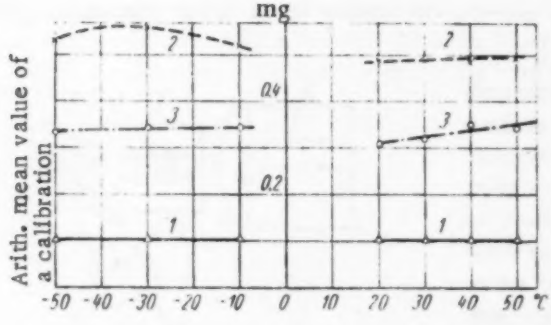


Fig. 1. 1) ADV-200 balances; 2) AD-200 balances; 3) VA-200 balances.

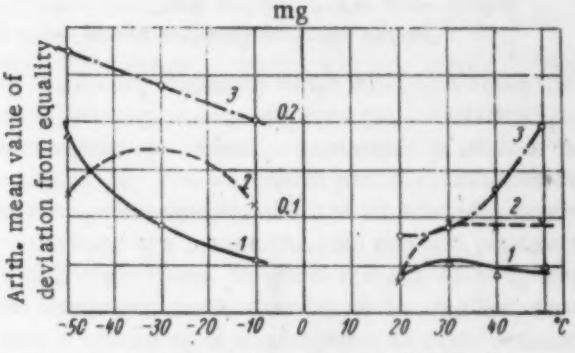


Fig. 2. 1) ADV-200 balances; 2) AD-200 balances; 3) VA-200 balances.

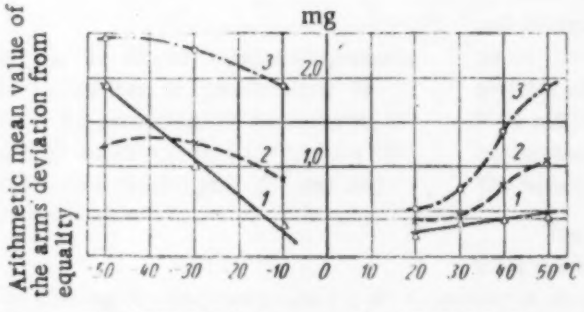


Fig. 3. 1) ADV-200 balances; 2) AD-200 balances; 3) VA-200 balances.

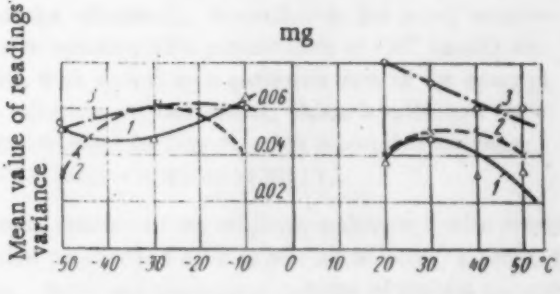


Fig. 4. 1) ADV-200 balances; 2) AD-200 balances; 3) VA-200 balances.

In order to find out the effect of such temperatures on analytical balances, the "Gosmetr" plant carried out systematic tests of balances of the VA-200 (10 samples), AD-200 (5 samples), and ADV-200 (5 samples) types. Only the balance arm units were subjected to temperature variations.

Each series of tests consisted in heating or cooling the balance arm during 6 hours at a given temperature with a subsequent exposure for 24 hours to the ambient temperature of the laboratory in which the balances were tested.

Altogether, seven series of tests were made: After the balances were received from the factory Technical Control Division they were heated up to + 30°, + 40°, and + 50° C and cooled to − 10°, − 30°, and − 50° C, and then tested.

The metrological characteristics of the balances were established by the method specified by instruction 57-56 and each measurement was repeated three times. Figure 1 shows the arithmetic means of calibration values (for all the balances of a given type) which were obtained in all the above series of tests. The values of calibrations at 20° C correspond to the measurements made initially on receiving the balances from the Technical Control Division. Figure 1 shows the results obtained with maximum loading of the balances; similar results were obtained with unloaded balances and with a load equal to 0.1 of the maximum.

Figures 2 and 3 show the arithmetic means of values of deviation from the equality of arms at 0.1 of the maximum load and at the maximum load, respectively.

The variance determinations are given in Fig. 4.

It will be seen from the data given in Figs. 1, 2, 3, and 4 that temperature effects of a limited duration cause practically no variations in the calibration of the balances and hardly affect the variance of their readings. The deviation from the equality of arms changes considerably after each heating or cooling exceeding the specified tolerances (Fig. 3). The variations in the arm inequality are due, it would appear, to the weakening of the knife-edge bearing fixings caused by the difference in the linear temperature coefficient of the balance arms and the fixing screws.

The biased nature of the bearing displacements is due to the use of adjusting screws placed mainly on one side of the balance arms.

RADIATION MEASUREMENTS

CALIBRATION OF γ-DOSIMETERS BY MEANS OF DIAPHRAGM BEAMS

Z. P. Balon, R. F. Keller, G. P. Ostromukhova, and V. N. Tuchin

Various dosimetric instruments are now widely used for γ-radiation measurements. In order to ensure the correctness and uniformity of these measurements, it is necessary to establish a calibration technique for these instruments.

The calibration of γ-dosimeters is usually made by means of radioactive preparations. The doses of γ-radiations are either calculated (if the parameters of the preparation are known) or measured by means of standard apparatus. Measurements of working instruments are made both with diaphragm and wide beams (approximately 4π). In the present work, instruments were measured in diaphragm γ-ray beams.

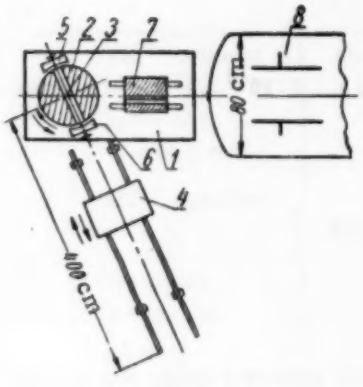


Fig. 1. 1) Device using a diaphragm; 2) container; 3) preparation; 4) table for mounting the instrument; 5 and 6) mobile protection blocks; 7) calibrated diaphragm; 8) standard equipment.

In the x-ray measuring laboratory of the All-Union Scientific Research Institute of Metrology, a dose of a standard γ-radiation preparation which is measured on reference equipment is taken as the basic reference value [1, 2]. This equipment provides measurements of radiation doses of quantum energies of 0.3 to 1.5 Mev with an error of 3-4%. The construction of a normal chamber makes it possible to work with narrow diaphragm beams (angle of aperture 45-65'), whereas for commercial instruments much wider beams are required, since their chambers have a volume up to several thousand cubic centimeters.

In order to ensure a correct transfer of the unit size from the reference equipment to the commercial instrument when calibrating by means of diaphragm beams, special equipment was constructed and investigated at the laboratory. According to the safety requirements the equipment operates with preparations of Co^{60} having an activity of 5 curies, thus providing a radiation dose of the order of 3000 mC/sec at a distance of one meter, which is sufficient for testing instruments intended for investigating protective measures. The schematic of the circuit is shown in Fig. 1.

The equipment consists of the diaphragm device 1 with container 2 for the radioactive preparation 3, a bench 3.7 m long, a table 4 for placing the instruments, and a set of reference preparations. Auxiliary equipment consists of special portable containers and a wall-mounted safe for keeping the holders with the standard preparations.

The container of the diaphragm device is mounted on bearings and can be turned about a vertical axis over 360° by means of a worm gear. Two radiation directions are used in the laboratory, one along the bench for calibrating instruments and the other along the axis of the normal camera. The preparation in a special holder is inserted into the container channel which has exchangeable diaphragms with 30, 14.5, and 8 mm holes. The side cylindrical surface of the container carries at the height of the channel two lead cubes 5 and 6 of 10 x 10 x 10 cm for screening the beam and for protection from the radiation coming from the side of the preparation holder.

The axis of the output channel for γ-rays and the longitudinal axis of the bench are in the same vertical plane. The radiator in its holder is first placed from the safe into the portable container and then transferred into the container of the diaphragm device.

Figure 2 shows the geometrical disposition of the beam. The beam diameters at various distances from the preparation with different limiting diaphragms are given in Table 1.

TABLE 1

Diameter of the limiting diaphragm, mm	Diameter of the beam at a distance R, cm					
	70	140	210	280	350	420
30 ω_3=4°20′	12	25	36	48	60	72
14.5 ω_2=2°5′	6	14	18	26	31	39
8 ω_1=1°30′	3	6	10	13	16	19

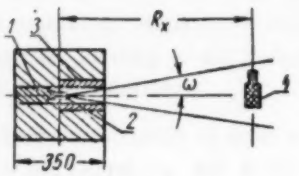


Fig. 2. 1) Holder; 2) Preparation; 3) limiting diaphragm; 4) chamber.

At a distance of 140 cm from the preparation it is possible to obtain irradiation fields of a diameter of 25, 14, or 6 cm according to the diaphragm used, whereas the beam of the reference equipment at the same distance has a diameter of the order of 3.7 cm.

Let us denote by P_0 the value at a distance of 1 m of a radiation dose determined by measurements on the reference equipment. The value of dose P for other distances R to which the calibrated instrument is set is determined taking into account the attenuation of the radiation in air and the isotope decay:

$$P=P_0\left(\frac{100}{R}\right)^2 e^{-\mu(R-100)}K, \qquad (1)$$

where μ is the radiation attenuation constant in air (for γ-radiations of Co^{60} $\mu = 6.8\cdot 10^{-5}$ cm^{-1} at a pressure of 760 mm Hg and a temperature of 20° C).

The correction for the isotope decay is determined from the formula:

$$K = e^{-0.69\frac{t}{T}}, \qquad (2)$$

where T is the isotope's half life; and

t is the time elapsed between the measurement of the preparation on the reference equipment and its use for calibration.

Preparations of Co^{60} (No. 1 and No. 2) and a preparation of Cs^{137} (No. 3) are now being used in the laboratory as standard radiators.

The activity of the preparations and the value of the dose of γ-radiations were measured on the reference equipment of the radiometric and x-ray measuring laboratory of the All-Union Scientific Research Institute of Metrology. The characteristics of the preparations are given in Table 2.

The values of the radiation doses given in Table 2 were obtained in measurements by means of a narrow beam with an aperture angle of $2\omega = 1°20'$ when the dimensions of the standard chamber were much larger than the section of the measured beam (diaphragm chamber). The chambers of commercial dosimeters are varied in shape and are, as a rule, of the thimble type, but their dimensions are always smaller than the cross section of the measured beam.

In view of the above it can be expected that the radiation actually measured in thimble-type ionization chambers by means of diaphragm beams will not coincide with doses calculated from (1).

We carried out measurements with a standard and an extrapolation chamber and also with commercial instruments using thimble-type chambers under different conditions of irradiation: with the cross section of the beam smaller or larger than the chamber.

The extrapolation chamber 30 cm in diameter with polystyrene electrodes 4 mm thick operated under conditions similar to a normal chamber of standard equipment: the diameter of the measured beam was smaller than that of the measuring electrode of the chamber. The measuring volume of the chamber was calculated from the actual cross-sectional area of the beam in the chamber and the distance between the electrodes.

Under these conditions of irradiation the doses measured by means of beams with an angle of 45' to 2° 20' on the standard equipment or on the extrapolation chamber were practically the same (with an error of ± 5%).

Additional measurements made in an extrapolation chamber at various distances from the preparation (70, 100, 150, 200, 250, and 300 cm) with $\omega = 1°20'$ and $\omega = 2°20'$ provided results which agreed with (1) with an error of 1-2%.

Measurements according to the second condition of irradiation were made with commercial instruments using thimble-type chambers with different limiting diaphragms ($\omega_1' = 1°10'$; $\omega_1 = 1°30'$; $\omega_2 = 2°5'$; $\omega_3 = 4°20'$; $\omega_4 = 8°40'$ and $\omega_5 = 26°30'$) and at varying distances from the preparations.

The various beam widths were attained by changing the position of the preparation in the container and by exchanging the limiting diaphragms; moreover, in all the instances the dimensions of the preparation were smaller than the hole in the diaphragm and the chambers were completely covered by the beam.

TABLE 2

Sample No.	Isotope	Cover	Activity in curies	Value of the dose in mC/sec at a distance of 1 m	Correction for radiation absorption in the preparation
1	Co^{60} cylinder d = 5 mm l = 10.8 mm	Aluminum 0.1 mm thick	November 5,1957 1.12 ± 0.03	July 25, 1957 330 ± 10	0.80
2	Co^{60} cylinder d = 5 mm l = 15 mm	Without a cover	November 25,1957 0.276 ± 0.010	December 27, 1957 82 ± 3	0.74
3	Cs^{137} powder in a metal ampoule d = 10 mm l = 10 mm	Steel cover	November 25,1956 1.12 ± 0.03	April 10, 1956 105 ± 3	0.93

Note: The value of the γ-radiation dose was measured from the ends of the preparation.

Measurements were made by means of the following instruments:

1) KID-1 with chambers 1.5 cm in diameter and 6 to 3 cm long, with 2.5 mm (l = 6 cm) thick walls made of a special plastic;

2) DIM with cylindrical chambers 50 mm in diameter, 50 to 100 mm high, and walls made of: a) graphite-covered pressboard 1 mm thick; b) graphite-covered pressboard 1 mm thick and a 1 mm aluminum sheet, and also with a cylindrical chamber from instrument MRM-1, 12.5 cm in diameter, 15 cm high and a wall made of 0.8 mm thick celluloid and 1 mm sheet aluminum;

3) laboratory instrument LR-1 and chambers: a) spherical with an external diameter of 8 cm, and an ionization volume of 60 cm^3; b) cylindrical, with a diameter of 8 cm, height of 17 cm, and an ionization volume of 513 cm^3; c) flat, with a diameter of 12 cm, a height of 1.6 cm, and an ionization volume of 92.6 cm^3; the chamber walls were made of organic glass 4 mm thick (a and b) and 3 mm thick (c).

Measurements made with Co^{60} γ-radiations were identical for all the chambers. Figures 3 and 4 show, for instance, the readings of instrument KID-1 and LR-1 with a flat chamber. A decrease in the solid angle of the beam leads to a fall in the instrument readings, whereas with a decreasing distance to the preparations, the difference in readings rises. The dotted line corresponds on these graphs to the inverse square law of distances with the attenuation of the radiation in air taken into account. The distances which correspond to the meeting of the curves for different values of ω were taken as the basis of measurements.

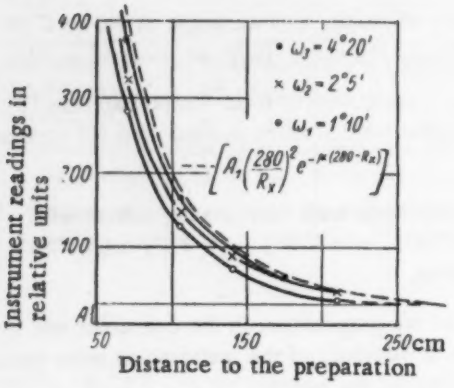


Fig. 3

When instruments are calibrated, it is important to establish which of the instrument readings corresponds to the dose measured on the reference equipment. Considering the distances to the normal chamber and the increased air pressure in it during measurements, it is possible to assume that these conditions are best met at the largest distances (3-4 m).

These considerations are confirmed by the measurements made with chambers of the laboratory instrument LR-1. The values of doses were calculated in mC/sec from the ionization volume of the chamber and the electrical charge measured during the investigations.

Measurements were made with spherical, cylindrical, and flat chambers with aperture angles of ω = = 1°5'; 1°30'; 2°5'; 4°20'; and 26°30' at a distance of 3 m.

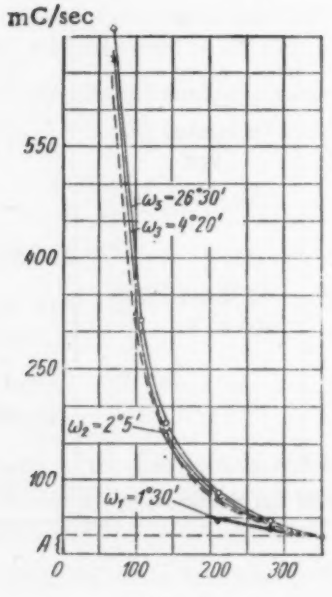


Fig. 4

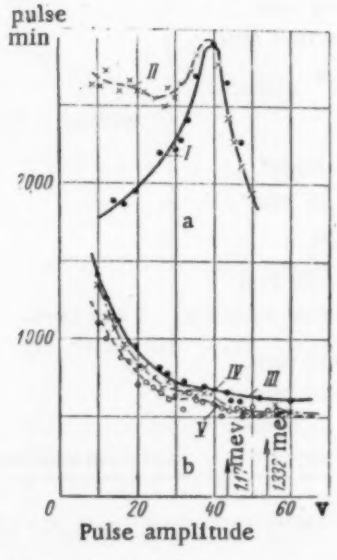


Fig. 5. a) Distance to the preparation 105 cm; I) beam diameter 5 cm (ω = 2°44'); II) beam diameter 78 cm (ω = 20°10'); b) distance to the preparation 280 cm; III) beam diameter 206 cm (ω = 21°35'); IV) beam diameter 48 cm (ω = 4°07'); V) beam diameter 8 cm (ω = 0°50').

The error in measuring the value of the dose in mC/sec with instrument LR-1, based on the instrument's parameters and its readings, amounts to 4-5%.

On the basis of these measurements, it was established that the values of doses measured on the LR-1 instrument at that distance do not depend on the aperture angle and coincide with the values obtained on the reference equipment with an error of ± 2.5%.

At shorter distances the instrument readings depend on the aperture angle; moreover with a changing distance to the preparation the relations to each other of the instrument readings with various apertures ω rise with a decreasing distance, thus making the readings deviate from the inverse square law of the distance. At distances smaller than 3.5 m, measurements will agree with formula (1) only under certain conditions which determine the beam width and have to be selected for each type of chamber (its shape, dimensions, material of the walls).

It was found useful to check the spectral composition of the beam for its various configurations. Investigations were carried out by means of a scintillation spectrometer with a NaI(Tl) crystal. The 30 mm long and 17 mm high crystal was mounted in a brass cylinder. Its dispersed radiation appears as a constant component in the measuring results which are shown in Fig. 5. Measurements were made at distances of 105 and 280 cm. Under all the irradiation conditions, the crystal in the protecting cylinder was completely covered by the beam.

It will be seen from Fig. 5 that an increase in the solid angle of the beam and in the distance to the preparation leads to a rise in the spectral components which correspond to softer radiations than the basic one of Co^{60} [3].

Spectra of radiations with different beam diameters at a distance of 280 cm are very similar to each other and possess an intensive soft radiation on whose background the peak corresponding to the Compton scattering in the crystal (see curves for R = 105 cm) is hardly distinguishable. The spectral intensity increases a little with a larger solid angle of the beam.

The spectral composition of radiations greatly affects ionization measurements.

When the chamber is approached to the preparation or the solid angle of the beam decreased, the relative effect of the soft radiations in the spectrum of Co^{60} is decreased. This may be one of the reasons for the decreased readings of the instruments at short distances.

However, the relative effect of the dispersed radiation depends on the shape and the dimensions of the chamber and the configuration of the beam.

Moreover, as the investigations of Kaye and Binks [4] and Hine [5] have shown, the walls of thimble chambers which are placed in a directed beam do not work uniformly. The greatest effect is produced by the wall nearest the entrance of the rays, whereas the back wall's effect is insignificant. The relative effects of the ionization current components differ according to the dimensions and the shape of the chamber, and the effective center of the chamber does not coincide with its geometrical center.

These circumstances make it impossible at present to establish uniform factors accounting for the configuration of the beam when measuring by means of thimble chambers.

On the basis of the above results, it is possible to recommend that in checking instruments by means of directional diaphragm beams the distance at which the instrument readings no longer depend on the values of ω be first determined; then the radiation dose will correspond to a standard preparation dose measured by means of reference equipment; next a curve should be plotted which corresponds to the inverse square of the distances taking into consideration the attenuation in air, and then an irradiation should be selected which will provide conformity with the inverse square of distance law within the range of the measurement distances.

Under all the measurement conditions the chamber should be fully irradiated by the beam.

Such a measurement technique will provide greater accuracy in transferring a measurement unit from the reference equipment to the commercial instruments and a greater degree of uniformity in the calibration of instruments made in laboratories of different establishments.

LITERATURE CITED

[1] K. K. Aglintsev, G. P. Ostromukhova, and M. F. Yudin, Trudy VNIIM [In Russian] (1957), No. 30 (90).

[2] K. K. Aglintsev, F. M. Karavaev, A. A. Konstantinov, G. P. Ostromukhova, and E. A. Khol'nova, Atomnaya Energiya No. 2 (1956).

[3] G. V. Gorshkov, Gamma-Radiations of Radioactive Bodies [In Russian].

[4] G. W. Kaye and A. W. Binks, Amer. J. Roentgen and Radium Therapy 40, 1, 80-91 (1938).

[5] Hine, Phys. Rev. 82, 755 (1951).

MEASUREMENT OF FAST NEUTRON FLUXES WITH AN INDIVIDUAL DOSIMETER

R. S. Belova and I. I. Yankovskii

The possibility of measuring neutron flux by means of individual type DK-0.2 dosimeters was reported in [1]. It was noted that a flux of $6.5 \cdot 10^6$ fast neutrons per 1 cm^2 obtained on a cyclotron produces a deflection of a DK-0.2 dosimeter shadow path of approximately 2.5 scale graduations.

The dosimeter readings expressed in scale graduations and determined by neutron radiation will equal (1):

$$R_1 = \frac{2.5}{6.5 \cdot 10^6} I = 3.84 \cdot 10^{-7} I, \quad (1)$$

where I is the neutron flux in neutrons per 1 cm^2.

The experiments conducted by us consisted in placing DK-0.2 dosimeters at various distances from polonium-beryllium sources of neutrons and subjecting them to irradiation during 24-30 hours; dosimeter readings were taken by observation every hour. A calculation of the neutron flux emitted by the source was made and the ratio between the neutron flux irradiating the dosimeter and the dosimeter readings determined.

In the case of a polonium-beryllium source the dosimeter will be affected not only by the neutron flux, but also by the accompanying gamma-radiation produced by the source, and the readings of the DK-0.2 dosimeters will be determined by both components.

We based our calculations on the data obtained from [2] according to which the value of the dose of the accompanying gamma-radiation will be related to the neutron flux in the case of a polonium-beryllium source by the following expression:

$$P_\gamma = \frac{0.00463}{3600} I' = 1.286 \cdot 10^{-6} I',$$

where I' is the neutron flux per 1 sec per 1 cm^2; and

P_γ is the value of the accompanying gamma-radiation dose in milliroentgens per second.

The readings of the dosimeter in graduations of the scale (each graduation of the DK-0.2 dosimeter is equal to 10 milliroentgens), due to the accompanying gamma-radiations, will be expressed by the formula

$$R_2 = \frac{1,286 \cdot 10^{-6}}{10} I = 1.286 \cdot 10^{-7} I. \quad (2)$$

The total readings of the dosimeter according to (1) will be:

$$R = R_1 + R_2 = 3.84 \cdot 10^{-7} I + 1.286 \cdot 10^{-7} I = 5.126 \cdot 10^{-7} I. \quad (3)$$

The experiments were conducted under conditions where any possibility of the effect of back-scattering from the walls and other surfaces on the dosimeters was practically eliminated. Dosimeters which in repeated preliminary checks exhibited practically no self-discharging tendencies during 24 hours were chosen for the tests. The results of the experiments are shown in the table.

Distance from the dosimeter to the source, cm	Neutron flux during 25 hr	Expected readings in scale graduations	Actual readings in scale graduations
35	$2.205 \cdot 10^7$	11.3	9.5
50	$1.080 \cdot 10^7$	5.5	4.5
75	$4.806 \cdot 10^6$	2.5	2.0

It will be seen from the table that the actual dosimeter readings amounted to 84-80% of the readings calculated by formula (3) which was derived on the basis of the data in [1]. The 20% error thus obtained cannot be considered as accidental and determined by the inevitable inaccuracy of the readings. It seems more correct to assume that the calculated values, determined from [1] for the case of a polonium-beryllium source, are too high; the conversion coefficient of $5.126 \cdot 10^{-7}$ used for expressing the dosimeter readings in terms of neutron flux should be reduced to $4.2 \cdot 10^{-7}$.

The experimental results fully confirm the possibility of using dosimeter DK-0.2 for measuring neutron flux. For the case of irradiation by neutrons from a polonium-beryllium source, we recommend the conversion formula:

$$I = \frac{1}{4.2 \cdot 10^{-7}} R = 2.38 \cdot 10^6 R \qquad (4)$$

where R are the readings of the dosimeter DK-0.2 in scale graduations.

According to existing regulations, the maximum permissible irradiation by neutrons during a working week is determined by the neutron flux of $6.5 \cdot 10^6$ neutrons per 1 cm^2. According to (4) such a neutron flux will produce a deflection of the dosimeter shadow trail of approximately 2.73 graduations. Since the dosimeter provides an accuracy of reading of one-half graduation, the possible error of reading will amount to ± 0.25 graduations (i.e., it is possible to read on the scale between 2.5 and 3.0 graduations), or approximately 10%.

This accuracy makes it possible, in our opinion, to use dosimeter DK-0.2 for controlling the irradiations of the personnel engaged in work where polonium-beryllium sources of neutrons are used (for instance, in neutron logging of oil or gas wells). In such instances individual dosimeters are distributed to the personnel after being charged at the beginning of each week.

Since the chambers will be used for a relatively long period (6 days) it will be necessary to take into account the possibility of self-discharging, which would raise the readings. In order to check the dosimeters' self-discharging tendencies, they should be repeatedly tested for the amount of self-discharge (each time for the duration of 6 days) before being issued to the personnel. The experimentally obtained value of the increase in readings for each dosimeter due to self-discharge should be noted and taken into account when the readings are checked at the end of the working week. It is recommended to check the value of the self-discharge periodically. It is not recommended to set aside one chamber as a standard for checking self-discharge, since different dosimeters possess different characteristics for the same self-discharge.

LITERATURE CITED

[1] V. V. Bovin and A. I. Mosharov, Atomnaya Energiya No. 2 (1957).

[2] A. G. Istomina and I. B. Keirim-Markus, Meditsinskaya Radiologia No. 4 (1958).

DETERMINING THE MASS CONTENT OF BINARY SYSTEM COMPONENTS BY THE METHOD OF ATTENUATING β- AND γ-RADIATIONS

V. S. Merkulov and A. V. Klimushev

There are many problems in measurement technology which involve determining the mass content of binary system components and can be successfully solved by the method of attenuating β- and γ-radiations. This method has already been used for analyzing such systems as vapor and water, soil and water in excavating-pump equipment, coal and mineral inclusions, sulfur and hydrocarbons, etc. This method can be used for the analysis of any binary system whose components react differently to the chosen radiations. Moreover, it is immaterial whether the components are in the form of unmixed layers, mixtures, alloys, or solutions.

We shall distinguish two types of reactions of the binary system components to the selected radiations:

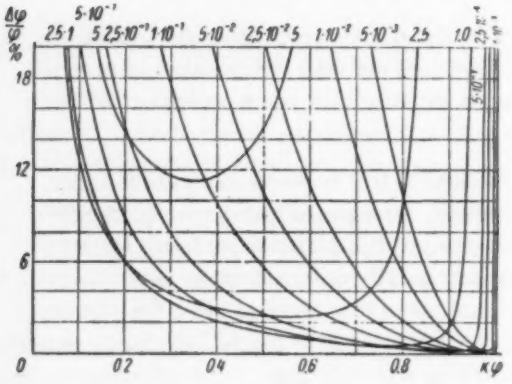
1. The mass attenuation constants μ_0 of the components are equal. This will occur when:

a) β-and hard γ-radiations are used, whose μ_0 in the first approximation does not depend on the chemical (element) composition of components (with the exception of hydrogen);

b) β-and γ-radiations of any energy level are used, and the two components have similar constituent elements. In particular, this holds for a system consisting of the same substance in two different states of aggregation.

2. The mass attenuation constants of the two components are different. This applies to the case when soft γ-and x-ray radiations with quantum energies smaller than 0.3-0.5 Mev are used and the components differ by their constituent elements.

Below we shall derive formulas for determining the mass content of components and evaluate the errors of measurements for the first of the above instances.



When the systems under test are being irradiated by β- or γ-radiations, the schematic of the measuring circuit is extremely simple. The system is placed between the source and the receiver and the radiation flux enters the receiver after passing through the tested media. The intensity of radiation is changed according to the exponential attenuation law, which holds in the first approximation for β and for narrow beams of γ monochromatic radiations. Let us express this attenuation in the form:

$$\ln \frac{I_0}{I} = \mu_0 (M_0 + M). \qquad (1)$$

Here I_0 and I are intensities of radiation respectively before and after the system under test and its envelope;

μ_0 is the mass attenuation constant;

M_0 is the mass of the protecting walls (membranes) in the path of the radiations; and

M is the mass of the tested binary system in the path of the radiations.

Let us define the mass content φ as the ratio of the first component mass m_1 to the total mass of the system $M = m_1 + m_2$ (m_2 being the mass of the second component):

$$\varphi = \frac{m_1}{M}.$$

Then, if the volume under test is completely filled by the binary system, the following equation will obviously hold:

$$\frac{M\varphi}{\rho_1} + \frac{M(1-\varphi)}{\rho_2} = D, \tag{2}$$

where ρ_1 and ρ_2 are the densities of the first and second components, respectively; and

D is the radiation path length in the system under test.

Solving (2) with respect to φ and introducing the notation $k = 1 - \frac{\rho_2}{\rho_1}$, we obtain

$$\varphi = \frac{1}{k}\left(1 - \frac{D\rho_2}{M}\right). \tag{3}$$

By using Eq. (1) and introducing a notation for the intensity of radiation when protective membranes are present in its path $I_1 = I_0 e^{-\mu_0 M_0}$, we shall obtain for φ the basic formula:

$$\varphi = \frac{1}{k}\left(1 - \frac{\mu_0 D\rho_2}{\ln \frac{I_1}{I}}\right). \tag{4}$$

In order to determine φ from (4) we should know I and I_1 and also the values of μ_0, D, ρ_1, and ρ_2. If the values of μ_0, D, ρ_1, and ρ_2 cannot be found from tables or determined accurately in advance, they can be excluded from (4) by means of additional calibration measurements of the intensity of radiation for known mass contents of the tested system's components. For these measurements, it is convenient to make $\varphi = 0$, $I = I_2$ (only the second component is present) and $\varphi = 1$, $I = I_3$ (only the first component is present). Expressing $\mu_0 D\rho_2$ and k in terms of the intensities I_1, K_2, and I_3 and substituting these expressions in (4), we obtain:

$$\varphi = \frac{\left(\ln \frac{I}{I_2}\right)\left(\ln \frac{I_1}{I_3}\right)}{\left(\ln \frac{I_1}{I}\right)\left(\ln \frac{I_3}{I_2}\right)}. \tag{5}$$

Let us now evaluate the errors of measurement and at the same time derive a criterion for the optimum choice of an isotope.

By differentiating (3), we obtain the following expression for the relative error $\Delta\varphi/\varphi$ in terms of the relative error $\frac{\Delta M}{M}$:

$$\frac{\Delta\varphi}{\varphi} = \frac{D\rho_2}{M - D\rho_2} \cdot \frac{\Delta M}{M}. \tag{6}$$

It is known that if only the static error of measuring radiation is taken into account the value of $\frac{\Delta M}{M}$ is equal to ([1]):

$$\frac{\Delta M}{M} = \frac{e^{\frac{\mu_0 M}{2}}}{\mu_0 M\sqrt{I_1}} = \frac{e^{\frac{\mu_0 M + M_0)}{2}}}{\mu_0 M\sqrt{I_0}}. \tag{7}$$

The value of the measurement error $\frac{\Delta M}{M}$ according to (7) depends on μ_0, which represents the "hardness" of the chosen radiation, and on I_0, which is proportional to the activity of the source. If μ_0 is varied, with a constant value for the activity of the source, expression (7) acquires a minimum at

$$\mu_0 = \frac{2}{M + M_0}. \tag{8}$$

Condition (8) provides a criterion for the choice of an isotope taking into consideration the protecting membrane.

Expression (6) differs from (7) only by a factor which is independent of μ_0. Hence, criterion (8) remains valid, and by substituting the value of M, it is possible to write it as

$$\mu_0 = \frac{2}{M_0 + \frac{D\rho_2}{1 - k\varphi}}. \tag{9}$$

In working over a wide range of φ it becomes impossible to satisfy accurately condition (9), and it becomes necessary, for a rational choice of an isotope, to make a fuller analysis of the relative error value $\Delta\varphi/\varphi$ in measuring the mass content. By substituting (7) and (6) and developing M, we obtain:

$$\frac{\Delta\varphi}{\varphi} = \frac{e^{\frac{\mu_0 D\rho_2}{2(1-k\varphi)}}}{\mu_0 D\rho_2 \sqrt{T_1}} \cdot \frac{(1-k\varphi)^2}{k\varphi}. \tag{10}$$

We calculated from formula (10) curves for the errors $\frac{\Delta\varphi}{\varphi} = f(k\varphi)$ (see figure) in which $k\varphi$ was taken as the independent variable and the product $\mu_0 D\rho_2$ as one of the parameters in the range of 5 to $5 \cdot 10^{-3}$. I_1 was taken as the other parameter whose value for the purpose of the calculations was taken as $I_1 = 10^4$ pulses. For other values of I_1, the value of the error varies as $\sqrt{\frac{10^4}{I_1}}$.

LITERATURE CITED

[1] V. S. Merkulov, Izmeritel'naya Tekhnika No. 4 (1958).*

[2] Z. L. Miropol'skii and M. A. Styrikovich, Izvest. Akad. Nauk SSSR, OTN No. 9 (1955).

* See English translation.

REVIEWS AND REPORTS

AN AUSTRIAN MOBILE INSPECTION LABORATORY

The Austrian State Administration for Inspection and Measurement Techniques produced an experimental model of a mobile inspection laboratory for checking measures and measuring instruments which are widely used in the rural districts of Austria. Satisfactory experience was gained from its operation showing that the efficiency of the work was raised, the inspection requirements were satisfied more rapidly, and the network of stationary laboratories can be reduced.

The equipment is mounted on a trailer truck, thus achieving a relatively good maneuverability with a smaller load on the car axle. When the laboratory remains for testing in one place for a long time, the cab can be used for other purposes.

The equipment is placed both in the trailer and the cabin. The cabin carries a set of 104 weights of 20 kg each. The weights are stored in built-in boxes, two of which are placed on the left and right-hand sides of the car between the front and back axles with 40 weights in each box; the third box is placed in the rear part of the cabin (under the coupling device) and contains 24 weights. This disposition of the weights is due to the necessity of obtaining the maximum possible pressure on the back axle of the car.

Standard wooden measuring rods are carried over the driver's cabin and used for checking large-capacity measures.

All the basic measuring equipment is carried in the trailer, which constitutes the laboratory proper. Four large work benches are placed along the walls of the trailer.

The bench placed to the right of the entrance door carries the standard mobile scales which are used for checking weights of 200 g to 20 kg, and remain, during transportation, fixed in their own positions. The bench has easily moving drawers which slide on ball bearing and guide rails. These drawers are intended for carrying sets of standard weights of various values. The weights are placed on sponge rubber and felt cushions.

Another bench with two standard scales for checking precision weights is placed opposite the first bench. The bench drawers hold reference measures of length and various accessories. To the right of the bench is the device for stamping the checked instruments.

By the side of the stamping device are located 15 weights of 20 kg each. A hook for checking steelyards and spring balances up to 400 kg is attached to the ceiling in the middle of the trailer near the entrance door.

The third bench serves to check table scales, liquid capacity measures, and other measuring instruments. Standard capacity measures of 0.1 to 10 liters are kept under this bench and in a wall cupboard. This bench is also supplied with drawers for instruments, hoses, electrical leads, etc.

The fourth bench, located to the left of the entrance, also serves to mount measuring instruments.

Small freight scales are checked on the floor near the entrance.

In the front part of the trailer a place is reserved for an office, which is also equipped with benches for sitting and sleeping.

All the measuring and auxiliary devices and instruments are kept in special cases which protect them from damage during transportation.

The checking of large freight scales and large capacity measures is done outside the trailer under an awning on the right-hand side of the trailer. The standard 100 liter capacity measure for large volumes and the standard counter are mounted at the rear on the outside right-hand wall of the trailer, at which point they are used.

The required water can be supplied from the water mains or, in their absence, by means of an electric pump with an output of 60 liters/min and a suction height of 20 m. In addition to the capacity measures, a 20 liter water tank is mounted inside the trailer, and serves for filling with water small capacity measures when they are being checked. There is also a small basin with an external drain for washing capacity measures.

An automatically controlled oil-fired heater is used for heating the trailer during the winter. The hot air is circulated by an air pump placed under the work benches. The heater is mounted under the trailer.

The laboratory is ventilated by means of three electric fans placed in the roof of the trailer. The air pump, fans, and heater run off a 12 v storage battery. This battery also serves to light the trailer in the absence of the cabin. Switching facilities are provided on the distribution board for emergency use of the car starter battery instead of the trailer battery when the latter is out of order. The laboratory is normally lighted with fluorescent lamps which are supplied through a transformer from the line with any voltage from 120 to 380 v. An electricity meter is provided for measuring the energy consumed. A rectifier with the required switches is also supplied for charging the battery.

All the electrical equipment including several sockets and fuses is mounted on a special distributing board placed at the entrance of the trailer. As a safety measure, the trailer is grounded when external supplies are used.

In addition to the equipment already described, the laboratory is supplied with several folding tables and chairs which are used outside the trailer under the awning. Measuring equipment is placed on these tables.

When the trailer is detached from the cabin it is lifted on four special jacks, thus taking the pressure off the axle springs and placing the trailer in a horizontal position. Five built-in spirit levels serve to check the trailer's horizontal position: four levels are placed near the jacks and one at the rear of the trailer.

The total weight of the trailer with all the equipment amounts to 12,950 kg.

This mobile laboratory is designed for checking a limited range of instruments. Taking into consideration that the range of instruments checked by our State Inspection Laboratories is much greater, only a few technical features described above can be applied to the design of our State Inspection Laboratories.

LITERATURE CITED

[1] Rust, Mobile Inspection Laboratory [Russian translation] (Austrian State Administration for Inspection and Measurement Techniques Press, Vienna, 1958).

DISCRETE MEASURING OF CHANGING FLOWS BY MEANS OF VARIOUS TRACERS

G. P. Katys

In measuring high-speed variable flows, it is often impossible to introduce measuring elements into the flows. In such instances, systems operating on the basis of tracers formed in the flow itself are normally used. These tracers form an inseparable part of the flow and experience all the speed variations of the flow. The principle of operation of these measuring systems consists in introducing, by means of special devices, tracers in the flow (ionic, radioactive, optical, or thermal) and measuring the displacement time of the tracers together with the flow between two determined sections of the pipe. On the basis of the known distance between these sections and the measured time interval the speed of the flow is determined. In measuring the flow by these means it is necessary to account for the speed distribution along the cross section of the channel. This can be achieved by introducing an appropriate coefficient related to the nature of the flow.

Although in measuring devices of this type a considerable variety of methods is used for forming tracers, in the main only two methods are used for continuous measurement of the time interval during which the tracer is displaced together with the flow from the place where it is formed to the place of its recording. For this purpose either closed systems in which the frequency of tracer formation is proportional to the speed of flow are used, or systems in which the frequency of tracer formation is constant and the time interval between the formation of the tracer and its recording after it has been displaced with the flow is measured.

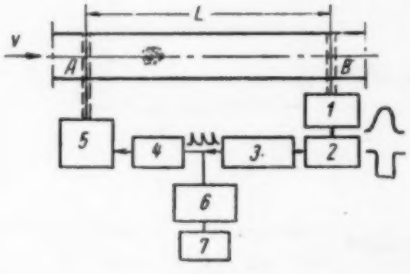


Fig. 1

A version of the second system is also described in which the phase shift is measured between traces which are formed at a constant frequency [1]. In this case, the density of the tracers must be uniform along the axis of the flow. Two sensitive elements are used for measuring; they are placed along the flow and determine the phase shift between the corresponding tracers. The tracer repetition frequency is selected to make the phase shift in the required range a single-valued function.

Let us now examine the first system of measuring the speed of tracers (Fig. 1). Element A which forms the tracers is placed in the measured flow. Recorder B is placed along the flow at a certain distance L from A. When the tracer is formed it moved with the flow toward the recorder. When the tracer passes in front of the recording element a pulse is produced in it and fed to amplifier 1 and trigger 2, which forms electrical rectangular pulses. The rectangular pulses are converted in unit 3 into pointed pulses, amplified in unit 4, and operate element 5 which forms tracers. This element produces in the measured flow a new tracer and the whole cycle is repeated. The tracers follow each other in definite intervals of time which vary according to the rate of flow. The distance between the generator and the recorder is set at 150-300 mm. The measuring signal is tapped off in front of amplifier 4 to a frequency meter 6 and a recording instrument 7. The measuring signal consists of a sequence of voltage pulses whose frequency is proportional to the speed of the flow.

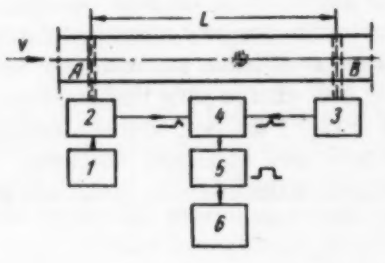
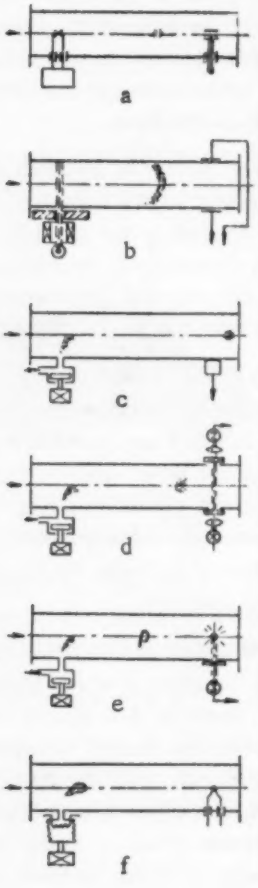


Fig. 2

Let us now examine a measuring circuit in which the tracers are formed at a constant frequency (Fig. 2). Element A which forms the tracers is placed, as in the first case, in the flow, together with element B which records the tracers. Signals from generator 1 and the sensitive element 3 are fed to the computing device 4-5 which continuously measures the time taken by the tracers to flow along the set distance. The operation of the electronic time-counting device consists of the following. The pulse coming from element 2, which forms the tracer, and corresponds to the beginning of the time count, trips the blocked Kipp relay 5, and the lagging pulse received from the tracer recorder 3 returns the Kipp relay to

its initial position. Thus, the duration of the Kipp relay signal is made equal to the time of the tracer flow between the selected pipe cross sections, and the pulse repetition frequency is equal to the tracer formation frequency. The Kipp relay output signals are transformed into a dc voltage which is proportional to the ratio of the Kipp relay pulse duration to the pulse repetition frequency, i.e, it is inversely proportional to the speed of the flow. This voltage is recorded by instrument 6.

We described above the measuring devices used in the methods under consideration. Let us now examine the methods of forming tracers in the measured flow (Fig. 3).



Type of tracer used	Essential properties of the medium
Ion tracers produced by electric discharges	The medium should be a gas at a low temperature and humidity and free from ionized flows
Ion tracers produced by radioactive radiators	ditto
Radioactive tracers	Gases and liquids with any physical properties (including high temperature flows)
Optical tracers (opaque)	Transparent gases and liquids
Optical tracers (radiating)	High temperature gas flows
Thermal tracers	Liquids and, to a smaller degree, gases at a low temperature

Fig. 3

Systems with a periodic spark ionization of the flow. By means of a special device, local pulse ionization of the flow is attained and the time it takes the ionized volume to travel from the place of ionization to the receiver is measured [2-3]. The ionizing device which produces the tracers is placed inside the pipeline (Fig. 3a). The ionized volume travels with the gas flow and is registered by the ionization counter, consisting of a tube with an insulated central electrode. The measuring electrodes of the counter are at different potentials, and when the ionized cloud approaches them a pulse of ionic current flows across them. The voltage pulse thus obtained is fed to the input of the amplifier of the measuring system. The system shown in Fig. 1 was used with this arrangement. By means of such an instrument air speeds in the range of 30-600 km/hour were measured. When the speed was decreased below 30 km/hour the ionic pulse became too weak, owing to diffusion in the radial and axial directions and recombination of ions.

Systems with flows ionized by means of modulated radioactive radiations. A flow meter circuit working on the basis of modulated radioactive radiations is shown in Fig. 3b [4-7]. A radioactive isotope is placed next to the pipeline along which the gas is flowing. The radiations of the isotope are modulated by means of a mechanical or electromagnetic device in such a way that they enter the flow periodically with the frequency of modulation. The ionized tracers thus obtained are registered by the receiver which is placed at a certain distance from the ionizer. The receiver consists of two thin plates fixed to the pipeline and insulated from it. These plates are fed with a large enough voltage to make the collection time of ions which have entered the collector field much smaller than the travel time of the ionized volume. At the instant the ionized volume passes the collector, a voltage pulse is fed to the input of the measuring system. In this instrument, the circuit shown in Fig. 2 was used for measuring purposes. The instrument scale in these flow units can be made almost linear. The error in measuring the gas flow in a steady state is equal to 1.5-2%, according to experimental data. At gas flow speeds less than 4 m/sec the measuring pulses become diffused and measurements are difficult. Measurements at high speeds are limited by the necessity of raising the collector voltage.

A mechanical shutter can be used for modulating α-and β-radiations. For modulating γ-radiations, the thickness of the shutter must be so large that it is more convenient to place the radioactive isotope on a revolving disk or vibrating slide and fix in front of it a screen with an opening. In an electromagnetic modulator, used with β-radiations, the latter pass through an alternating magnetic field which deflects them from the pipeline [8]. The ionized volumes are produced in the pipeline when the magnetic field becomes zero.

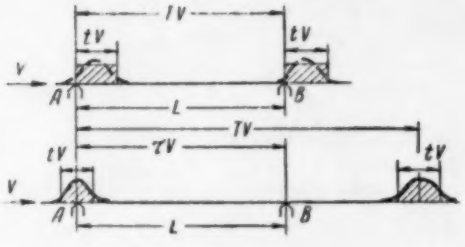


Fig. 4

This measuring method has been developed in the Institute of Automation of the Academy of Sciences, USSR [4-8]. Recently, a similar flow meter with a mechanical modulation of β-radiations and a compensation measuring circuit was developed in the All-Union Scientific Research Institute of Thermal Instruments.

Systems with periodic introduction into the flow of definite doses of radioactive isotope. The measurement methods so far examined cannot be applied to gases with a considerable degree of ionization or to hot gases in which the lifetime of ionized volumes is extremely short. For such measurements, it is necessary to use an instrument which operates on the basis of introducing radioactive substances into the flow [9-11]. For this purpose a doser is fixed to the pipeline in order to supply it periodically, by means of an electromagnetic mechanism and a piston ejector, with definite doses of radioactive isotopes (Fig. 3c). An indicator of radioactivity is placed in the path of the measured substance. When the radiating particles pass the indicator the latter produces an electric pulse which is fed to a measuring circuit. For measuring purposes circuits shown in Figs. 1 and 2 can be used. In determining the speed of gas flows, radioactive xenon, krypton, or radon are used [10]. For liquid flows various liquid and powdered isotopes can be used. The drawback of this method consists in the constant input of radioactive isotopes which pollute the flow.

Systems with optical tracers. For measuring transparent flows it is possible to use devices which produce opaque tracers [12] consisting of some kind of powder, which is periodically injected into the flow by means of special dosers (Fig. 3d). A photoelectric device determines the time of passage of the opaque tracers from the place of their formation to the place where the pipeline is illuminated by a source of light. The pulse obtained from the photoelectric cell is amplified, converted, and fed to the input of the measuring system. Both closed and constant frequency systems can be used for measuring. The defect of this instrument consists in a certain degree of pollution of the flow.

This system can also be used for measuring the speed of a high temperature flow. In this instance, determined doses of a substance which on heating radiates a light of a definite spectral composition (Fig. 3e) are injected periodically into the flow. These radiating tracers pass in front of a transparent window in the pipeline behind which a color-selective photoelectric receiver is placed. The photocell produces pulses, which are fed to an appropriate measuring system (Fig. 2) when these radiating tracers pass in front of it. In these devices, the distance between the injection place of tracers and the recording place must be large enough to allow the tracer sufficient time to become luminescent.

Systems with thermal tracers. For measuring unheated liquid (and certain gas) flows with a stable temperature it is possible to use devices which form thermal tracers (Fig. 3f). An elastic bellows with a wire-wound heater which heats the flowing substance is attached to the pipeline. The bottom of the bellows is connected to an electromagnetic vibrator which periodically compresses the bellows, forcing out into the main flow determined doses of the heated substance. The thermal tracers thus obtained travel with the flow to a high-speed thermocouple placed at a certain distance from the bellows. The thermocouple records the passage of the thermal tracers. The vibrator and thermocouple leads are connected to a measuring circuit. This device can operate as a closed system or at a constant frequency of tracer formation.

Let us now examine the basic parameters of the measuring systems used in these devices and compare them to each other. Let us take the measuring system whose tracer formation frequency is determined by the speed of the flow. Figure 4 (top part) shows the relation of the tracer size tv ($\underline{v}$ being the speed of the flow) to distance L between element A, which produces the tracers, and element B, which records them, (T is the period of the tracer formation, $\underline{t}$ is the duration of a tracer formation). When a closed system is used there is, during the entire measuring time, only one tracer at a time in length L. At the instant the tracer arrives at the recorder B, element A produces the next tracer (neglecting the operation time of the electronic system). This instrument measures the mean speed during period T (without registering the actual speed variation in that period). This instrument thus measures an uninterrupted sequences of discrete mean speeds (i.e., a continuous stepped sequence of discrete mean speeds). The volume flow can then be determined from the formula:

$$G = LFfa,$$

where F is the cross-sectional area of the channel;

f is the signal frequency; and

α is the coefficient accounting for the distribution of the flow speeds in the cross section of the channel.

In this system the tracer formation period T is determined by the measured speed $\underline{v}$ of the channel and distance L ($T = \frac{L}{v}$). The dynamic properties of the system (which characterize the system's ability to measure instantaneous variations in the speed of the flow) for a given mean speed of the flow are determined by the value of T. The smaller the duration of T the larger will be the number of discrete speed measurements which a given system will perform in a unit of time. Since the minimum time of T is determined by the time $\underline{t}$ taken to form a tracer (in order to avoid adjacent tracers flowing into one T must not be smaller than 2t), the dynamic properties of the system are also determined by time $\underline{t}$. The time $\underline{t}$ depends on the method of forming tracers. Time $\underline{t}$ will be minimum for the spark method of forming ion tracers or the method of modulated radiations. Time $\underline{t}$ will be maximum for mechanical-type injectors (radioactive, optical, or thermal).

Distance L should be chosen on the basis of making the tracer formation time $\underline{t}$ not more than 0.5 T (i.e., $t \leq 0.5\ L/v$), since then one tracer can cover the entire distance L, thus affecting the operation of the system. In view of the fact that in this system an increase in the flow speed $\underline{v}$ decreases the value of T, a rise in speed, with other conditions being equal, improves the dynamic characteristics of the system. The maximum speed is determined by the condition $T > 2t$.

Let us examine the measuring system in which the tracers formation frequency is constant and their travel time in the flow changes. Figure 4 (lower part) shows the relation between the linear dimensions of the tracer (tv) and distance L between elements A and B. In the operation of this system there may be periods when there is one tracer in the measuring section L or no tracers at all. The system measures the mean speed of the flow for time τ during which the tracer traverses distance L. In the subsequent period $(T - \tau)$ when the tracer has passed the recorder B but a new tracer has not yet been formed, the speed of flow is not being measured. The mean measurement of speed for time τ, which is obtained on the sensitive element, is then averaged for the entire period T by the conversion system. Thus, in this system, no measurements at all are made over a certain time interval, and for that period the speed of the flow is determined by extrapolating the preceding time interval during which measurements were being carried out. The volume flow G can be determined from the formula:

$$G = LFf\frac{T}{\tau}a.$$

In order to improve the dynamic properties of the system, it is desirable to make period T small, but not smaller than τ, the time required for the tracer to travel over distance L for a given speed of flow. Under these conditions, the value of τ is determined by the tracer formation time t. For a correct operation of the circuit (without the tracers running into each other) it is necessary that $t \leq 0.5\,\tau$. The choice of L for a given t and v is determined by the relation

$$t < 0.5\frac{L}{v}.$$

It is necessary to observe condition $T > \tau$, since with $T < \tau$ the circuit stops working. With a decreasing speed of the flow the system may stop working owing to a rise in time τ. Hence, T must be larger than $\frac{L}{v_{min}}$, where v_{min} is the minimum flow speed measured. In choosing the value of τ it is necessary to take into account the life of the tracers (i.e., the preservation of a steep leading and trailing edge of the tracers).

A closed measuring system has better dynamic properties than a system with a constant frequency of tracer formation. The application of the first system is limited in the region of high speeds, and the second system in that of the low speeds of flow. The general dynamic properties of the instruments are determined in the main by the type of tracers used, and the best dynamic properties are possessed by instruments using high-speed tracers.

LITERATURE CITED

[1] L. V. Mel'ttser, Izmeritel'naya Tekhnika No. 5 (1957).

[2] G. L. Mellen, Gas flow speedometer, Electronics 23, 80-81 (February, 1950).

[3] W. C. Cooley, Rev. of Sci. Instr. 23, 4, 151-154 (1952).

[4] N. N. Shumilovskii and L. V. Mel'ttser, Doklady Akad. Nauk SSSR 106, 4 (1956).

[5] N. N. Shumilovskii and L. V. Mel'ttser, Priborostroenie No. 3 (1956).

[6] N. N. Shumilovskii and L. V. Mel'ttser, Priborostroenie No. 11 (1956).

[7] L. V. Mel'ttser, Application of Radioactive Methods for Automatic Control of the Flow and Dust in Gas Media [In Russian] Collection of Work on Automation and Remote Control (Academy of Sciences, USSR Press, 1956).

[8] D. I. Ageikin, L. V. Mel'ttser, and N. N. Shumilovskii, Avtomatika i Telemekhanika, 18, 7 (1957).*

[9] A. Babenko and Karutkin, Radio No. 5 (1955).

[10] E. W. Voice, J. of the Iron and Steel Institute 177, 4, 423-427 (1954).

[11] D. H. Hull, Using tracers in refinery control, Nucleonics IV, 13, 4, 18-21 (1955).

[12] N. A. Mal'tsev, I. M. Romanov, and A. G. Sharygin, Zavodskaya Laboratoriya 22, 9 (1956).

* See English translation.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

CHECKING TAXIMETERS IN TAXICAB ESTABLISHMENTS

M. S. Varivoda

The L'vov State Inspection Laboratory of Measurement Equipment carried out in 1957-1959 State tests of taximeters in taxicab establishments of Zakarpatsky, Nikolaev, Zhitomir, Kherson, Vinnitsa, Poltava, Chernovitsy and other regional automobile trusts. The checking was carried out with special mobile equipment. As the result of the State checks several important defects were brought to light.

1. In a number of taxicab establishments second tariffs were not taken off the meters, which registered 3 roubles per kilometer in taxis with a rate of 1 rouble 50 kopeks per kilometer, and 4 roubles per kilometer in taxis rated at 2 roubles per km, thus providing the possibility for taxi drivers to charge the passengers a double rate;

2. defects in the clockwork mechanism used for recording the taxi's waiting time. The clock mechanisms were outside the specified accuracy tolerances;

3. defects in the "dial" and fare counters, and the counters of the total fare distance and the over-all distance covered;

4. several taximeters were mounted on a slant, had indistinct numbering, broken glass, etc.

In some of the taxicab establishments the repair of taximeters was carried out in their own shops which, as a rule, were not equipped for good quality repairs and lacked standard instruments and equipment for checking the quality of these repairs.

On completing the repairs, the taxicab establishments did not, as a rule, submit the taximeter for State testing but sealed them on the spot, despite important defects, and mounted them in taxis, thus breaking the rules of the Committee of Standards, Measures, and Measuring Instruments, which provide for State testing of the repaired taximeter by agencies of the Committee. On the basis of the data obtained in State checking, the Ministry of Automobile Transport and Main Roads of the UkrSSR has issued an order obliging the heads of the taxicab establishments of the Republic to eliminate these defects.

DRAWING BOARDS WITH GUIDING RULES

V. S. Golub

An important defect of drawing boards with guiding rules is the bending of the latter when they are displaced along the boards– a bending which is accentuated in long and thin rules and leads to inefficiency and errors in their use.

In order to ensure a straight and smooth movement of the rule, it is suggested to use a geared connection between the rule and the board. The rule is supplied with two gears which are firmly fixed on a common spindle, are placed at the ends of the rule,and engage in two toothed racks fixed to the sides of the board in the direction of the movement of the rule.

Such a board should find wide application, for instance,in drawing high-precision graphs of zero beats in wavemeters.

If the board is made in the shape of a truncated segment and it is necessary to provide a rotary movement to the rule over the segment, the guiding rule and board should be supplied with tapered gears.

INFORMATION

CONFERENCE ON AUTOMATION AND MECHANIZATION OF THE CONTROL EQUIPMENT IN LINEAR AND ANGULAR MEASUREMENTS

V. Ya. Éidinov

A Republican Scientific and Technical Conference on the latest achievements in automation and mechanization of control operations in linear and angular measurements and the adoption of modern measuring equipment and methods in engineering and instrument-making was held on October 26 to 28, 1959, in Kiev. The Conference was organized by the accredited Administration of the Committee of Standards, Measures, and Measuring Instruments attached to the Council of Ministers of the UkrSSR, the Khar'kov State Institute of Measures and Measuring Instruments, and the Ukranian Republican Administration of the Scientific and Technical Society of the Instrument-Making Industry.

The Conference was attended by workers belonging to the instrument-making industry and scientific-research institutes of the Ukraine, the RSFSR, and other union republics, and dealt with production control, measurement techniques, and development of new control and measurement equipment.

The papers and reports read at the Conference dealt with new efficient automatic means of production and technological control, modern practical organizational methods of control and inspection, new developments in the measurement of lengths and angles with great precision, and improvements introduced in various control and measuring operations.

Chief Engineer of the Interchangeability Bureau E. R. Dvoretskii read a paper on the present state and developments in automatic control of dimensions in engineering, reviewing the existing efficient schemes and designs in the control equipment sphere.

M. I. Mekler reported on the standardization of modern linear and angular measuring equipment.

Representatives of the plants "Kalibr" and "LIZ", I. M. Tsirul'nikov, S. P. Protopopov, and V. A. Samsonov reported on the work carried out and planned in the production of new measuring instruments.

V. S. Vikhman reported on the results of experimental research in utilizing in engineering projection and television techniques in combination with various kinds of electrical high-speed calculating machines.

Lenin prize winner N. E. Kopanevich (Moscow) reported on the new equipment for measuring components in the process of their manufacture developed by the Interchangeability Bureau.

The head of the Metrological Department of the Engineering Institute in Karl-Marxstadt(GDR), G. Trumpold, reported on new means and methods for measuring rough surfaces.

Several papers dealt with a further extension of the interference method in measuring dimensions. L. K. Kayak demonstrated and explained the operation of a 30 meter interference comparator made by the All-Union Scientific Research Institute of Metrology and designed for checking wire and tape measures up to 30 m in length as well as stiff measures (rods, racks, and rules) up to 4 m in length.

N. V. Trofimov reported on instruments developed by the All-Union Scientific Research Institute of Metrology and designed for measuring linear measures by the interference method (by comparison with a block gauge and using optical multiplication by means of a Fabry-Perot standard) or by direct measurement in light wavelengths.

V. Ya. Eidinov (VNIIK) reported on the application of the interference method to angular measurements.

G. S. Simkin reported on the work carried out by the Khar'kov State Institute of Measures and Measuring Instruments in developing an interferometer based on microwaves and on its application for measuring large dimensions.

A. N. Zhuravlev's paper (MAI) dealt with the accuracy and reliability of engineering production measurements. The author suggested a technique for calculating tolerances in certain measuring methods and posed certain problems in this sphere.

N. N. Markov read a paper on methods of controlling geared connections, their choice and application in varying conditions, and on the development work carried out in this sphere by the Interchangeability Bureau.

B. A. Konstantinov (Leningrad) reported on the application of magnetic recording for controlling the kinematic accuracy of gear-cutting machines.

The suggestion of the L'vov Polytechnical Institute on the adjustment and control of automatic machines by means of the mean read-out method was reported by L. P. Vladimirov.

S. M. Skorodzievskii (Kiev) reported on static methods of analysis and control and their application to the regulation of technological processes in engineering.

A. V. Abrosimova reported on a number of development projects of the Khar'kov State Institute of Measures and Measuring Instruments in the sphere of practical inspection methods of linear and angular measurements.

G. V. Boiko and M. I. Repin (Khar'kov), A. I. Chernyak (KhTZ), L. I. Markin (Dnepropetrovsk), M. P. Shevchenko (Kiev), and others dealt in their papers with their experience in inspection and measurement work.

The Conference adopted a resolution urging speedy introduction of automation and mechanization of control operations in the sphere of linear and angular measurements and the spreading of modern methods and means of measurement in engineering and instrument making.

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SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

AN SSSR	*Academy of Sciences, USSR*
FIAN	*Physics Institute, Academy of Sciences USSR*
GITI	*State Scientific and Technical Press*
GITTL	*State Press for Technical and Theoretical Literature*
GOI	*State Optical Institute*
GONTI	*State United Scientific and Technical Press*
Gosénergoizdat	*State Power Press*
Gosfizkhimizdat	*State Physical Chemistry Press*
Goskhimizdat	*State Chemistry Press*
GOST	*All-Union State Standard*
Gostekhizdat	*State Technical Press*
GTTI	*State Technical and Theoretical Press*
IAT	*Institute of Automation and Remote Control*
IF KhI	*Institute of Physical Chemistry Research*
IFP	*Institute of Physical Problems*
IL	*Foreign Literature Press*
IPF	*Institute of Applied Physics*
IPM	*Institute of Applied Mathematics*
IREA	*Institute of Chemical Reagents*
ISN (Izd. Sov. Nauk)	*Soviet Science Press*
IYap	*Institute of Nuclear Studies*
Izd	*Press (publishing house)*
LÉTI	*Leningrad Electrotechnical Institute*
LFTI	*Leningrad Institute of Physics and Technology*
LIM	*Leningrad Institute of Metals*
LITMiO	*Leningrad Institute of Precision Instruments and Optics*
Mashgiz	*State Scientific-Technical Press for Machine Construction Literature*
MGU	*Moscow State University*
Metallurgizdat	*Metallurgy Press*
MOPI	*Moscow Regional Pedagogical Institute*
NIAFIZ	*Scientific Research Association for Physics*
NIFI	*Scientific Research Institute of Physics*
NIIMM	*Scientific Research Institute of Mathematics and Mechanics*
NIKFI	*Scientific Institute of Motion Picture Photography*
NKTM	*People's Commissariat of the Heavy Machinery Industry*
Obrongiz	*State Press of the Defense Industry*
OIYaI	*Joint Institute of Nuclear Studies*
ONTI	*United Scientific and Technical Press*
OTI	*Division of Technical Information*
OTN	*Division of Technical Science*
RIAN	*Radium Institute, Academy of Sciences of the USSR*
SPB	*All-Union Special Planning Office*
Stroiizdat	*Construction Press*
URALFTI	*Ural Institute of Physics and Technology*
TsNIITMASh	*Central Scientific-Research Institute of Technology and Machinery*
VNIIM	*All-Union Scientific Research Institute of Metrology*

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

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